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CONSONANT-TO-VOWEL COARTICULATORY EFFECTS IN ENGLISH AND FRENCH

* * * *

AN ACOUSTIC AND PERCEPTUAL STUDY

by

Donald H. Schweyer

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

Romance Linguistics

Department of Romance Languages

Edmonton, Alberta

Spring 1996

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled *Consonant-to-Vowel Coarticulatory Effects in English and French: An Acoustic and Perceptual Study* submitted by Donald H. Schweyer in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Romance Linguistics.

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John J. Ohala

19 October 1995

For Shirley, Reta, and Harold

—wife, mother, and late father—

my three most constant sources

of support, stability and love

ABSTRACT

This thesis describes an investigation of the acoustic and perceptual dimensions of the influence of consonantal environment on the high vowels of Standard French and Canadian English. Its primary goal is to cast light on the nature of the task of phonetic correction for English-speaking learners of French.

The thesis begins with a review of literature from the traditions which have directed most second-language (L2) phonetic research in recent decades. Issues arising out of these theories are considered in light of current approaches to the pedagogy of phonetic correction. Finally, a theory of first-language (L1) interference in L2 learning is elaborated—one which places the source of phonetic difficulty in learners' perception.

There follows a review of literature on the phenomenon of consonant-to-vowel coarticulatory influence, which concludes that, while contextually-induced variability has been shown to be a fact of both production and perception of English vowels, little is known about the parallel processes in French. The experimental design is presented and hypotheses are proposed.

Results from the spectral analysis of speech samples show that consonantal environment has greater influence on the /u/s of English and French than on the other high vowels; however, the degree of acoustic "fronting" of /u/ in dental/alveolar context is much smaller in French than in English. In both languages, perceptual boundaries between vowels, determined on the basis of listeners' identifications of synthetic signals, show relatively small contextually-induced shifts. These findings account in part for the results of another perceptual test (using naturally produced words), in which French listeners identified as French /y/, 1 of 5 English /u/s in velar and labial environments, 3 of 5 in alveolar environment.

These findings challenge the traditional notion that French /y/ is a particularly difficult sound for English-speaking learners, since their L1 inventory has no such sound, and that French /u/, having a counterpart in the English system, presents a far lesser degree of difficulty. Pedagogical implications are discussed and directions for future research are suggested.

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Credit for this thesis will be attributed to one name only, but it is not the product of the efforts of only one person. The contributions of several must be noted here.

The people of Concordia College willingly tolerated in their midst a colleague who, for far too long, carried less than his share of the burden. In all of that, they did not cease to offer their encouragement and support, both moral and concrete. I thank them all. Particular gratitude goes to President Richard Kraemer, who relieved me of all non-teaching responsibilities for two full years, in order that I might devote myself as fully as possible to the completion of this thesis.

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technological. All questions whose answers I could find nowhere else were brought to him. Both of these scholars were sought out because of their extraordinary depth and breadth of understanding. Their expertise, their time and their patience are greatly appreciated.

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INTRODUCTION

This thesis describes a contrastive experimental investigation of the coarticulatory effects of consonantal environment on the acoustic products and on the perception of the high vowels in Canadian English and European French. Its goal is to shed additional light on the task of second-language phonetic correction in general, and on that task for English-speaking learners of French in particular, especially with regard to the difficulties associated with those French high vowels.

The plan of the thesis is as follows: Following this introduction, Chapter 2 gives, first, a brief presentation of the broad traditions that have directed most of the second-language phonological research conducted over the course of the last half-century, and secondly, an overview of current approaches to the teaching of French pronunciation to English-speaking learners. Chapter 3 considers some issues which emerge out of those traditions of research and pedagogical approaches and, on the basis of that discussion, elaborates a theory of first-language interference in second-language pronunciation. Chapter 4 reviews some literature dealing with consonant-to-vowel coarticulatory effects in English and French, and outlines

the design of the experiment. In Chapter 5 the results of that investigation are presented and discussed. Chapter 6 draws conclusions from those results, focusing on the application of the findings in the pedagogy of French pronunciation, and suggests a few topics for future research.

TRADITIONS IN SECOND-LANGUAGE SPEECH RESEARCH

The last half-century has witnessed the emergence of three broad theoretical approaches to second-language speech research. The purpose of this chapter is to present a brief, chronologically-ordered introduction to these traditions and, secondly, to offer a few cursory observations concerning some programmes currently being used in courses in phonetic correction for English-speaking learners of French. The goal is to provide a description of the "state of the union" between research and application, which, it is hoped, will provide a useful framework for the consideration (in the following chapter) of various issues within the three traditions.

THE CONTRASTIVE ANALYSIS HYPOTHESIS

It is probably within the natural order of things that those who know at least two languages are inclined to draw comparisons between various facets of those languages. Accordingly, throughout literature, we find contrastive statements about languages, such as the following, rather far-reaching, description of pronunciation patterns of the seventh century A.D.:

> All the Oriental nations jam tongue and words together in the throat, like the Hebrews and Syrians. All the Mediterranean peoples push their enunciation forward to the palate, like the Greeks and the Asians. All the Occidentals break their words on the teeth, like the Italians and Spaniards.[1]

It is no doubt equally natural that those who teach a second language (L2) will use such contrastive descriptions as a part of their pedagogical approach. In all probability, therefore, contrastive statements (improved over the course of the centuries, if not perfected) have been included in lessons for as long as teachers have tried to teach language. It appears, however, that the roots of *systematic* study of language contrasts can be traced to the 18th century (Ragusich, 1977: 9). And, since L2 pronunciation improvement was one of the goals of the contrastive descriptions of Sweet (1890), Viëtor (1890), and Sievers (1901), it is clear that this approach to instruction was the norm for at least some specialists around the turn of the present century.

Be that as it may, the middle part of this century, with the emphasis placed on behaviourist psychology and structural linguistics, saw the flourishing of the contrastive approach to second-language instruction, as is illustrated in the following claim by Charles Fries (1945: 9):

> The most efficient materials are those that are based upon a scientific description of the language to be learned, carefully compared with a parallel description of the native language of the learner.

---

1 Cited by Fromkin and Rodman (1978: 337) and attributed to Isidore of Seville.

This pedagogical claim does not appear to have been submitted to serious empirical testing. Nevertheless, during the following decade, there appeared a testable linguistic hypothesis which posited an explanation for the supposed superiority of teaching materials based on contrastive descriptions. In the preface to his monograph *Linguistics Across Cultures*, Lado (1957: vii) wrote:

> The plan of the book rests on the assumption that we can predict and describe the patterns that will cause difficulty in learning, and those that will not cause difficulty, by comparing systematically the language and culture to be learned with the native language and culture of the student.

This statement presents what Wardhaugh (1970: 124) called the "strong version" of the Contrastive Analysis (CA) hypothesis: namely, that, given adequate grammars of both the first language and the second language, the linguist will be able to *predict* all the points of difficulty for the learner. An alternative, "weak", version of the hypothesis begins with a set of L2 errors which have been observed to occur and has the contrastivist account for them on the basis of available linguistic knowledge (p. 126).

The contrastive analysis hypothesis was threatened by both theoretical and empirical considerations. As an example of the former, Wardhaugh (1970: 125) argued that the strong version "makes demands of linguistic theory, and therefore, of linguists, that they are in no position to meet", and dismissed it as untenable. And while he conceded that the weak version had

proved to be helpful, he saw it as having lost some of its importance in light of developments in generative-transformational theory and concluded that it may be "due for a period of quiescence" (p. 129).

An apparently more serious threat to the CA hypothesis came from some studies of L2 learner errors. As an example, taking as his point of departure the contrastive analysis of Lampach and Martinet (1963), Ragusich (1977) looked at the French pronunciation errors of English-speaking learners; he found that, while there was total agreement between observed areas of difficulty and those predicted, the predictions of the analysis with regard to the actual erroneous pronunciations of the subjects were far from perfect (p. 47). As a second example, Walz (1980) conducted an analysis of the errors of American learners of French (he does not describe or cite the specific contrastive analysis used for his study). Apparently on the basis of unpredicted substitutions (such as apical [r] for French [ʁ]), he concluded that "Productive teaching techniques cannot rely solely on the traditional theoretical comparisons of languages." (p. 430).[2]

---

2 Brière (1966) similarly found a considerable number of mismatches between predicted and observed areas of difficulty. By contrast, Lebrun (1975) studied the pronunciation errors in French of British-English learners primarily from the point of view of the contrastive work of Pierre Delattre (1965, 1966); she claimed a somewhat greater degree of success for the contrastive analysis than is found in these other studies.

ERROR ANALYSIS AND INTERLANGUAGE

It is a common occurrence that error analyses, such as those noted above, show instances of learner forms which appear not to be attributable to the influence of either the first language (L1) or the second.[3] As researchers tried to account for such forms, they began to see that there may be a myriad of causes for errors besides L1 interference. Realizing, then, that learner language is a multi-faceted phenomenon, Selinker (1972) coined the term "interlanguage" (IL) to designate this linguistic reality, which needs to be described and accounted for. Alternative labels such as "approximative system" (Nemser, 1971), "idiosyncratic dialect" (Corder, 1971), and "transitional competence" (Corder, 1981) contain slightly different emphases, but the concept remains essentially the same: namely, a language system lying between L1 and L2, which a learner gradually modifies into a closer and closer approximation of L2. The general trend, where adult learners are concerned, is for some elements of this language to "fossilize" (Selinker, 1972), or stop developing before they reach L2 norms.

In this same paper (p. 215), Selinker gave the following ordered list of processes held to be central in determining second-language behaviour:

---

3 The substitution of [r] for [ʁ] in Ragusich (1977), noted above, is a case in point. See also Nemser (1971:19) and Eckman (1981: 211).

1. Language transfer;
2. Transfer-of-training;
3. Strategies of second-language learning;
4. Strategies of second-language communication;
5. Overgeneralization of L2 material.

To these, other writers added other variables. Corder, (1967: 166) spoke of the learner's "built-in syllabus", a hypothesized list of linguistic elements which may specify an unalterable ordering for the learning of those elements. Richards (1976: 120) and Tarone (1972: 326) added linguistic universals. The list goes on—to the point where Brown (1980) was able to devote virtually an entire introductory monograph on L2 learning to the presentation and discussion of these variables.

THE SPEECH LEARNING MODEL

For a time, and in some circles of interlanguage scholars, a good deal of ink was used to refute the contrastive analysis hypothesis as untenable and to discount the importance of L1 interference in L2 speech.[4] That trend seems now to have faded away—or, if not that, at least to have been overshadowed

---

4 See, for example, Dickerson (1976), Dulay and Burt (1976) and Tarone (1978).

by another investigative movement which has its source in interlanguage studies: the Speech Learning Model.

The advantage which children appear to have over adults in mastering L2 pronunciation has generally been explained in terms of the "Critical Period Hypothesis" (e.g., Lenneberg, 1967; Scovel, 1969), according to which a reorganization of the central nervous system, occurring at about the age of puberty, diminishes one's ability to learn language. This explanation, however, has been called into question on a variety of grounds and it appears no longer to be accorded the degree of support that it once was.[5] On the question of these apparent adult-child differences, Flege (1981) cited evidence supporting the superior L2 pronunciation abilities of children, but noted other studies which suggested that some aspects of phonetic performance actually improve with age. The conflicting reports led him to conclude that "there does not appear to be evidence of a fundamental [neurological] difference between children and adults in their ability to learn to pronounce a second language" (p. 447).

As an alternative to the notion of the critical period, then, Flege (1981) proposed the "Phonological Translation Hypothesis", which was based on

---

5 For an overview of the issues involved with this hypothesis, see Flege (1988: 244-265), and Krashen (1973).

the assumption that the fundamental difference between child and adult language learners lies in their levels of "phonological development" (p. 448). He suggested that "a tendency by mature speakers to interpret sounds occurring in a foreign language in terms of sounds found in their native language may be a more important cause of foreign accent than any limitation on phonetic learning imposed by neurophysiological maturation" (pp. 448-9). Over the intervening years, this author published three restatements of the hypothesis (Flege, 1988, 1989a, 1995), into which he incorporated some changes motivated by subsequent research findings. In the latter two of these, the theory has been renamed the "Speech Learning Model" (SLM).

The SLM posits that L2 production errors have their source in perception and, thus, seems to follow in the tradition of Polivanov (1931) and Weinreich (1953), who held that learners identify L2 sounds with those of L1 and reproduce them in accordance with the phonetic rules of L1. However, while these earlier scholars placed this process (dubbed "interlingual identification" by Weinreich, 1953) at the level of the phoneme, the SLM places it in the *phonetic category*,[6] of which the following is said:

---

6 The original version of the SLM (Flege, 1981) also posited the phoneme as the relevant category. The change to the phonetic category is reflected in the abandonment of the name "Phonological Translation Hypothesis" (Flege, 1989a: 10).

> A phonetic category is defined as a locus at which sensory information associated with the production of a sound is stored and organized in long term memory, and related to the motoric representations ("motor programs" or "gestural scores") needed to produce the sound according to language-specific phonetic norms. Phonetic category representations specify context-sensitive allophones, not sets of phonetically distinct phones in complementary distribution with one another." (Flege, 1995: 3).

As units of perception, these categories contain the "'prototypes' which specify the ideal weighting of a set of independent and continuously varying properties that define each phonetic category" (Flege, 1989a: 21), as well as specifications of phonetic "tolerance regions" within which sounds will be identified as admissible members of the category in question. A sound falling beyond a given tolerance region may still be identified as belonging to the intended phoneme class, but would be recognized as a "distortion" (p. 22).[7] At the levels of both perception and production, the important difference between the phoneme and the phonetic category is that the latter contains context-sensitive information, while the former does not.[8] During the course of L1 development, these categories are progressively and gradually elaborated on the basis of all the tokens judged to belong to that class through "equivalence classification"—the process according to which tokens that are

---

7 It is presumably through comparison with prototypes that listeners are able to detect the presence of foreign accent.

8 Thus, for example, while the [tʰ] of English *tab* and the [t] of *bat* are members of the same phoneme class, they are posited to have separate phonetic categories (Flege, 1989a: 18).

perceptibly different are judged to be functionally identical. In speech, then, sounds are produced via the *phonetic realization rules* contained in the categories (Flege, 1995: 3).

The most recent version of the Speech Learning Model proposes the following central hypotheses (p. 3):

- " ... phonetic categories are needed for fully native-like production and the optimal perception of sounds."
- " ... the likelihood of a phonetic category being established for an L2 sound that differs perceptibly from the nearest L1 sound(s) will decrease with age because an increasingly large proportion of sounds encountered in an L2 will be equated perceptually with an L1 sound."

From the above core hypotheses emerge the following, more specific predictions (p. 6): The L2 speech of "late" learners (those who first receive massive L2 input after the age of seven) will be characterized by ...

- " ... fully native-like (i.e., unaccented) productions of L2 sounds that do not differ perceptibly from an L1 sound";
- " ... persistent accented productions of L2 sounds that differ slightly from the nearest L1 sound(s)";
- " ... fully native-like productions of L2 sounds that differ considerably from the nearest L1 sound(s)".

Note from the above that the author offers a prediction concerning each of three classes of sounds: those which (1) "do not differ perceptibly from an L1 sound"; (2) "differ slightly from the nearest L1 sound(s)"; and (3) "differ considerably from the nearest L1 sound(s)". The SLM posits that an L2 sound which is perceptually identical to a sound in L1 will be identified by all learners as members of the L1 phonetic category; in production, existing phonetic realization rules will cause the L2 sound to be uttered accurately. L2 sounds which differ greatly from any in L1 may be classified by late learners as members of some existing L1 categories during initial stages of input, but eventually they will be assigned separate L2 categories by all learners and will be realized in a native-like fashion (p. 4). In contrast, while early learners will establish separate categories for L1 sounds which differ only slightly from L1 sounds, late learners will continue to perceive them as members of L1 categories. In this case, where production is concerned, "gradual—but ultimately only partial—approximation to L2 phonetic norms is predicted" (p. 4). Flege adds that "this partial approximation comes about through the use of different realization rules, rather than from the implementation of phonemes via two distinct phonetic categories" (p. 5). Finally, this prediction concerning late learners' realizations of slightly different L2 sounds, based on

the notion of merged L1-L2 categories, leads to a further prediction with regard to L2 effects on L1:

- "... as late learners approximate L2 phonetic norms for a similar sound, production of its L1 counterpart will come to take on phonetic characteristics of the L2 sound." (p. 5)

CURRENT PRACTICE IN THE PEDAGOGY OF L2 PRONUNCIATION

The preceding cursory presentation of the three major traditions in the L2 speech research of recent years provides a vantage point for looking at current practice in the teaching of second-language pronunciation. In this section, following a brief introduction to one particular focus of contrastive studies, there will be given a broad characterization of the approaches taken in five programmes currently in use in L2 pronunciation courses.

Delattre's Modes

A characterization of approaches to the pedagogy of French phonetic correction for English-speaking learners demands a short introduction to one

of the broad focuses within the field of contrastive studies: articulatory settings.[9] These may be characterized as follows:

> ... articulatory settings are dialect-specific articulatory habits which, to an extent, determine the shape of individual phonetic segments. They function on a physiological level in which salient aspects are the direction and distance of articulatory movements in relation to the neutral speech position of the articulators and the manner in which those movements are effected. (Schweyer, 1987: 17)

Writing within this tradition, Delattre (1951) published a little manual of French pronunciation for English-speaking learners in which he defined the entire task of phonetic correction in terms of three contrasting "modes":

Modes of French	Modes of English
tendu	*relâché*
antérieur	*postérieur*
croissant	*décroissant*

These modes can be defined in the following terms:

> Broadly speaking, the *mode tendu* signifies tenseness of articulatory muscles during speech, and relative stability during articulatory states. The *mode antérieur* means a high proportion of front articulations. The *mode croissant* means primarily that open syllables predominate. The contrasting modes of English can then be defined in diametrically opposite terms. (Schweyer, 1987: 1)

In different writings, these modes are said to have various levels of power. Delattre (1953: 59) appears to present them primarily as intellectual constructs or generalizations under which a myriad of phonetic details can be gathered

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9 For an overview of this area of investigation, see Schweyer (1987).

for easy retention. By contrast, Matte (1982), a self-proclaimed disciple of Delattre, sees them as global habits which, when altered, will effect far-reaching change across a sound system (p. 43). While Delattre himself devoted a good deal of his career to the *demonstration* of the modes,[10] the governing power of the modes has never found the level of support that one would like to see (Schweyer, 1987).

Current L2 Pronunciation Programmes

A survey of five manuals currently in use in French pronunciation classes for English speakers reveals two distinct approaches to the task of phonetic correction. Of the five, Champagne-Muzar et al. (1986) is unique in that it relies entirely on recorded exercises with perceptual and performance tasks; no cognitive explanations are offered to assist learners in the attainment of their goal. The other four, Carduner and Hagiwara (1982), Dansereau (1990), Rochet (1990), and Valdman (1993), do include substantial explanation. Along coarse lines of characterization, these four manuals are very similar. All include general phonetic and phonological notions (in greater or less depth) in the material to be learned. All are more or less eclectic, defining the task of phonetic correction in several different ways

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10 See, for example, Delattre (1965, 1966).

whenever possible. More important for present interests, however, are the following generalizations:

1. All rely heavily on English-French contrasts.
2. All focus centrally on *articulatory* description.[11]
3. All place considerable importance on notions which are related to Delattre's modes.[12]

As examples of these generalizations, with respect to the *modes tendu* and *relâché*, Rochet (1990: 43-44) describes English diphthongized vowels as a product of muscular relaxation, in contrast to the "pure" vowels of French, which are the result of tense articulation.[13] Where the *modes croissant* and *décroissant* are concerned, this same author presents the tendency among English speakers to nasalize vowels before nasal consonants as the result of

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11 While this generalization does not apply very well to the overall *approaches* of all of these programmes, it does characterize well the *text* of the manuals. This divergence is not surprising, in that, while one can tell a learner how to *produce* some sounds well, one cannot tell them how to *perceive* them accurately (see Rochet, 1990: 7-8). Nonetheless, while there is not much to be *said* about perception, something can be *done* about it. The issue of the importance of perceptual training and the question of divergences within the programmes along these lines are treated in the following chapter. The point to be noted here is that these four programmes all place great importance on articulatory description, even if that importance cannot be considered to be unique.

12 While the greater preponderance of anterior articulations in French as compared to English is noted in some of these manuals (see, for example, Dansereau, 1990: 170), the *mode antérieur* is used less than the other two modes (or is not used at all) to explain phonetic difficulty or to provide a strategy for correction. In this, these authors appear to lend support to Schweyer's (1987: 27-36) arguments in favour of discarding the notion.

13 See also Dansereau (1990: 55), Carduner and Hagiwara (1982: 89), and Valdman (1993: 41-43).

consonantal anticipation (a product of their preference for closed syllables) and recommends open syllabification as a means of correcting the problem (p. 172).[14]

This chapter has attempted to introduce in brief the three theoretical frameworks which have dominated investigations of second-language speech acquisition over the course of the last half-century, as well as to describe in broad terms the current approach to the pedagogy of L2 phonetic correction. It is hoped that this coarse description will provide a useful vantage point from which to consider some issues involved in these models and in instructional practice. It is on these issues that attention is focused in the following chapter.

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14 See also Dansereau (1990: 116), Carduner and Hagiwara (1982: 115-117), and Valdman (1993: 113).

ISSUES IN RESEARCH AND APPLICATION

INTERLANGUAGE STUDIES

The statements made in the preceding chapter, with respect to the general characterization of four currently-used phonetic manuals, give no indication of instructional procedures having their source in Interlanguage research. If this is so, it is not because IL researchers abstained from making claims concerning the pedagogical implications of their work. For example, Richards (1971: 211) warned of the danger of giving excessive attention to points of L1-L2 difference, since that might impede perception of the total structure of the second language being studied. As a further case in point, after attempting to demonstrate that learners' faulty pronunciations are governed by variable interlanguage rules, Dickerson (1975) stated that, when practitioners grasped the import of this notion, "profound changes in point of view should result" (p. 406). Appearances would suggest that the warning has not been heeded and that the profound changes in point of view have failed to materialize. The manuals consulted here, with their emphasis on L1-L2 contrasts, thus stand as rather glaring examples of the rejection of the

pedagogical prescriptions made by IL scholars. Some of these prescriptions are discussed in the following paragraphs.

The most valuable pedagogical prescriptions made by Interlanguage writers were narrow in scope and concerned procedures which had already long been in use in language classrooms. As an example of these, Tarone (1972: 329-330) recommended the cognitive and systematic teaching of how articulation units (i.e., syllables) often do not correspond to language units (e.g., phonemes, words) and that proper blending of speech often demands that syllables cross word boundaries. The procedure certainly has merit, however, it was a central part of Delattre's (1951) approach—and that on the basis of its salience in English-French contrasts, rather than of IL findings.[15]

The broadest IL prescriptions with regard to L2 pedagogy—those which pointed to a total revamping of instructional approaches—appear to have been flatly rejected; and the reasons for this rejection are to be found within the very writings which proposed them. Two of these concern what Corder (1967:166) called the learner's "built-in syllabus"—a rigid, biologically pre-determined schedule according to which a learner must master the elements

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15 Other such practices, which have been recommended by IL scholars, but which were in use long before the notion of Interlanguage appeared, are the use of L2 singing (Tarone, 1972: 330); the adoption of graduated evaluation schemes which give credit for L2 approximation, as opposed to the use of all-or-nothing, "right"-vs.-"wrong", rubrics (Dickerson, 1975: 406); and the selective correction of student errors (Corder, 1981: 66).

of a new language. One prescription to emerge from this notion, noted by Corder (1981:77), is that of "explicitly teaching a sequence of approximative grammars of increasing complexity", or "actually teaching what is regarded by native speakers as erroneous". Although this author found the suggestion "interesting", he dismissed it as unworkable, "since it is unlikely to be accepted by teachers" (p. 78). In its place, he proposed the following:

> What can be done is to adopt a more realistic attitude to the language of the learner and by a selective correction of his so-called errors attempt to teach only what his interlanguage system [i.e., his built-in syllabus] permits him to learn at any given moment. (p. 78)

On the surface, this suggestion has merit: selectivity in error correction is a practical necessity in language classrooms, and it would be good for selection to be made on some systematic basis. However, both this recommendation and the preceding one lose their appeal when considered in light of two of this author's own pronouncements. The first, concerning the built-in syllabus, is that "the optimum logical sequence" for teaching linguistic elements remains unknown (p. 58). The second is broader in scope:

> Until we have overcome the theoretical and methodological problems of describing the approximative systems, or idiosyncratic grammars, of *individual* learners, or possibly groups of learners, we are not in a position to make firm generalizations about the phenomenon of interlanguage. (p. 67)[16]

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16 For a similar and slightly more recent statement, see Bley-Vroman (1983:16).

In light of these two statements, it is not surprising to find that practitioners have not adopted the two prescriptions in question. In the case of the former, in the absence of evidence in support of the efficacy of the procedure, teachers would be understandably reluctant to withhold the best L2 input they can provide in favour of a less accurate IL approximation.[17] In addition, since no one has yet been able to describe the shape of any built-in syllabus which may exist, neither recommendation is possible to implement.

A final prescription from Corder (1981: 77) involves, not a change of approach to phonetic correction, but the abandonment of the endeavour. Here, the author lays out a series of predictions concerning the shape of learners' systems. Among these, is that ILs will show greater individual-to-individual differentiation in young learners than in adults. Using this as a springboard, he offers the following recommendation:

> Efficient language teaching must work with, rather than against, natural processes, facilitate and expedite rather than impede learning. ... What has been discovered so far suggests that the nearer we can approximate language teaching to the learning of second languages in an informal setting, the more successful we shall be. (p. 77)

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17 Obviously, in those classes taught by late L2 learners, some of the input provided to learners may contain sounds which only approach target-language norms at best. Still, negative effects of such input can be kept to a minimum through the use of only native-speaker voices in the preparation of recorded materials.

Following this, he stresses the need for "a shift of emphasis in teaching away from a preoccupation with the grammar of the target language towards a concern with communication in the target language" (p. 78). He continues:

> The progressive elaboration of the interlanguage system of the learner is a response to his developing need to handle ever more complex communicative tasks. If we can control the level of these correctly, the grammar will look after itself. (p. 78)

In this recommendation we see the connection between Interlanguage studies and the "Communicative Competence" movement, which appears to have taken such a firm hold on current instructional practices in our schools. Some years ago, Valdman (1978: 567) stated: "*Communicative competence* is one of the most currently 'in' labels in the field of foreign language instruction." As it stands now, one is hard-pressed to find a basal introductory French textbook that does not include the term "communicative" in its title. And, as is no doubt the case with all "in" labels, the term has been accorded a plethora of meanings.

When Savignon (1972) coined the term *communicative competence*, she did so in connection with a proposal to include communication activities as a portion (20% of total class time) of language courses. During these sessions, emphasis would be placed on the transmission of effective messages; instruction in linguistic forms and correction of non-crucial errors (those

which do not block communication) would be avoided. As a follow-up to this, the appropriate role of these latter two practices in L2 instruction in general was accorded a good deal of discussion. In the end, a virtual rejection of the practices was incorporated into Krashen's (e.g. 1981) "Monitor Theory" of second-language learning. While a complete discussion of the Monitor Theory must remain beyond the scope of this review, it is mentioned here by way of introduction to one of its central parts—a claim which echoes Corder's comment above with regard to grammar looking after itself: "With comprehension [of meaningful L2 messages], my model predicts, acquisition of syntax will come." (Krashen, 1981: 109)

The above two statements can be interpreted to have several different meanings. While Krashen's claim is limited to syntax, Corder's term "grammar" might reasonably be assumed to encompass all linguistic forms, including the phonetic. If pronunciation correction is not meant to be included within these pronouncements, then, in the absence of specific prescriptions with respect to that area of language learning, one must be drawn to one of two conclusions: either that these two authors have nothing to say with respect to the pedagogy of phonetic correction, or that phonetic correction is an unimportant aspect of L2 learning. Where the first of these conclusions is concerned, of course, nothing remains to be said. With regard

to the second, if the value of pronunciation accuracy in L2 speech cannot be assumed,[18] then the fact that students choose to take courses in phonetic correction reveals a need which they feel and which, consequently, must be satisfied.[19]

If, on the other hand, L2 phonological forms *are* claimed to "look after themselves", then there is no place for courses in phonetic correction in the L2 curriculum; indeed, as is noted by Ross (1981: 234), there is no place for an L2 curriculum at all. Obviously, the authors of the manuals considered in this review have rejected these notions. Several points need to be noted in their defense. First, in light of the age-related differences in L2 learning mentioned by Corder (1981: 77),[20] one must question the appropriateness of a recommendation for a single "best" method for learners of all ages. Secondly, while this writer claims to base his recommendation on "what has been

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18 In this regard, Lebel's (1981: 298) spirited expression of that assumption is perhaps worthy of repetition: "L'étudiant dont la prononciation et la prosodie sont douloureusement ardues au point de faire fuir l'interlocuteur, cet étudiant ... veut à tout prix un correctif efficace et rapide."

19 The results of a survey of attitudes toward error correction recently conducted in Québec are especially illuminating in this regard. Nemni et al. (1993) asked learners of French and their instructors for their opinions and perceptions concerning the correction of errors in language classes. In most cases, the desires expressed by the learners were in diametric opposition to the principles of current pedagogical theory. Of particular interest for the present study are two of the findings from this survey: (1) correctness of expression was judged as being more important by learners than by their teachers, and (2) learners would like to have their errors—*including* their errors of pronunciation—corrected more often than they are.

20 On adult-child differences, see also Krashen (1981: 81).

discovered so far", he does not offer evidence which might in any way lead one to conclude that linguistic forms will look after themselves. And there is substantial evidence to the contrary. The writings of Flege and his colleagues are replete with examples of phonetic forms which have failed to look after themselves. To take just one example, one might note the investigation of Flege, Munro, and Skelton (1992), in which the English word-final /t/s and /d/s of native speakers were compared with those of two groups of Mandarin learners: an "experienced" group (who had lived in the United States for an average of 5.5 years), and an "inexperienced" group (who had spent an average of 0.9 years in the U.S.). The stops pronounced by all the Mandarin speakers were misidentified far more often than those of the native speakers of English; moreover, those of the experienced learners did not differ significantly from those of the inexperienced learners. To carry this argument further, one might note that the notions of "critical period" and "fossilization"—indeed, the very existence of such a field of investigation as L2 phonetic research—provide ample testimony to the fact that second-language phonetic forms do not fall into place during the course of natural (i.e., untutored) acquisition, and there is no reason to assume that they would do any better in a classroom where focus on forms is proscribed.

This section has attempted to show that, where the pedagogical approach to L2 phonetic correction is concerned, Interlanguage studies have yielded no help to the classroom instructor. However, this is not to say that the endeavours in question have been a waste of time and effort. What these studies have offered practitioners is a more conscious awareness of what they (perhaps) already knew on an intuitive level: namely, that L2 phonetic learning is influenced by more than L1-L2 differences. While what teachers have been given falls short of a set of systematic procedures for conducting error analyses without needing to fall back upon their intuitions (Corder, 1981: 59),[21] simply the knowledge of the multitude of variables which may be operant should improve their explanations of errors and, thus, help them to provide better corrective suggestions.

Beyond the walls of the language classroom, the most valuable contribution of Interlanguage studies is that they have drawn up a daunting list of variables which are likely to have some effect on the success of second-language learning. That list offers researchers a veritable multitude of research questions, all of which must be answered before the whole process of L2 learning and teaching can be fully understood. In addition to that, the

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21 For examples of the problems involved with error analysis, see "Error Analysis—The Study of Learners' Interlanguage", Chapter 9 of Brown (1980); and "The Role of Interpretation in the Study of Learners' Errors", Chapter 4 of Corder (1981).

notion of approximative systems has fostered the formulation of the Speech Learning Model and the huge body of empirical research which that model has inspired. It is on this theory that the following section focuses its attention.

THE SPEECH LEARNING MODEL

Nothing in the pronunciation manuals consulted for this review can be related to elements of the Speech Learning Model. If this is so, it is due in large part, no doubt, to the fact that the primary aim of the model is, as Flege (1995: 3) states, "to explain why, and to what extent, the ability to learn speech changes across the life span." Having no central, motivating interest in the teaching of L2 pronunciation, then, the author has refrained from drawing pedagogical implications from his model or his findings. It must be noted as well that, as it currently stands, the theory has failed to find sufficient empirical support to justify the drawing of such implications. Still, the SLM offers a comprehensive model of second-language speech learning. In this light, it is necessary to discuss the potential of the model.

As was noted above (pp. 12-13), at the heart of the Speech Learning Model is the claim that the difficulty which late learners experience with L2

sounds will vary as a function of their phonetic distance from sounds in the L1 inventory. According to a previous version of the SLM (Flege, 1989a), L2 sounds which have exact counterparts in L1 will, of course, present no difficulty, since the learner will simply use that L1 sound in his L2 speech. An L2 sound which is very distant from the nearest L1 equivalent will present serious difficulty in the initial stages of learning, but, after sufficient input, the learner will form a new phonetic category for that sound and will produce it in an unaccented fashion. By contrast, an L2 sound which differs slightly, but perceptibly, from an L1 counterpart will continue to be perceived as a member of an already-established L1 category and, consequently, will never be produced as better than an approximation of the target sound, and will contribute to the perception of that learner's speech as accented. In this version of the model, these three types of sounds were labeled "identical", "new", and "similar", and were held to represent three discrete categories of sounds, differing from each other both quantitatively (in their distance from L1 counterparts) and qualitatively (in that they are treated differently by learners). In the most recent version of the theory (Flege, 1995: 8), owing to difficulties associated with the determination of the "threshold" separating similar sounds from new ones, as well as to high inter-subject variability in the pronunciation of late learners, the qualitative distinction has been

abandoned. What remains is a distance-based continuum according to which difficulty increases as L2 sounds move from identity with L1 sounds towards moderate difference, then decreases as they move from there towards great difference. In this progression from moderate to great difference, it is predicted that there will be an increase in the *proportion* of late learners who establish new phonetic categories for the sounds in question and who, consequently, are able to produce them accurately.

For the time being, this hierarchy of difficulty of L2 sounds, based on distance from L1 counterparts, has not found the degree of empirical support that it requires in order to be affirmed as a reality. Most empirical studies relating to the question have yielded mixed support for the model. As an example of these, Flege (1995: 11) reports the results of an experiment (Flege, 1992) in which he recorded the English words *beat, bit, bet,* and *bat* produced by Spanish early and late learners. The words thus contained the "similar" vowels /i/ and /ɛ/, and the "new" vowels /ɪ/ and /æ/. These tokens were played to English-speaking listeners for a vowel identification test. For the new vowel /ɪ/, tokens of the experienced and inexperienced late learners were identified correctly in 61% and 51% of instances respectively. For /æ/, the rates were 73% and 70%. Words containing the similar vowels /i/ and /ɛ/ were identified more correctly. On the surface, it would appear that

these results contradict the predictions of the SLM, in that the similar vowels were produced with greater accuracy than the new ones. However, in this regard, the author states that the better success rate with the similar vowels may have been due to the speakers' substitution of Spanish vowels in these English words. Because these numbers emerge from an identification task—in which an approximation may serve as well as an an accurately produced form—the test simply fails to test predictions concerning new-similar differences.[22]

Flege (1995: 12) then proceeds to cite a series of studies dealing with the treatment given these same English vowels by Spanish learners. In the results of only one of these (Flege, 1991) is it possible to draw a comparison between vowels labeled as new and as similar. Here, Spanish learners identified the vowels of the same English words noted above as those represented in Spanish orthography by the letters *i, e, a, o,* or *u*, or as "not a Spanish vowel". While English /ɪ/ was identified as not Spanish more often as experience

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22 While the similar-new distinction as discrete classes has been abandoned in the formal presentation of the SLM, the author appears not to have abandoned it entirely in practice. That may be understandable in the case of the experiment in question, since it was conducted before the change to the model was effected. However, elsewhere, speaking for the present, Flege (1995: 12) shows that the notion of discrete classes has not disappeared:

> The vowel experiments just mentioned suggest that L2 learners are more likely to treat certain L2 vowels as new than others, which again raises the question of how cross-language differences are gauged, and *how large* the difference must be for a sound to be treated as new.

with English increased, English /i/ and /æ/ were labeled by all learners as Spanish *i* and *a* respectively. That is, the two new vowels /ɪ/ and /æ/ did not distinguish themselves as members of a group from the similar vowel /i/. Vowel-to-vowel differences were observed, but they failed to follow the group lines drawn by the SLM.

In this same article, Flege (1995: 10) cites four studies whose results "have supported the hypothesis that new vowels will be produced better than similar L2 vowels by inexperienced late learners, but have offered only limited support for the claim that new vowels can be mastered by experienced late learners." These four studies are briefly considered below.

In spite of the above claim, the results of the first of these studies offer little support for the productivity of the similar-new distinction. Flege's (1989a) presentation of the SLM is the preface to an investigation of the pronunciation of English vowels by Dutch-speaking late learners. The Dutch subjects for this experiment were divided into two groups (good English accent, poor English accent) of 10 subjects each (p. 76). A group of 8 native speakers of British English was formed to establish L2 norms (p. 62). Recordings of the speech of these subjects were made as they read the words *heat, hit, hot, hoot, hut,* and *hat* at the end of a carrier sentence. These speech signals were then digitized and all but the periodic portion of each vowel was

removed. This procedure yielded the isolated vowels /i, ɪ, ɒ, u, ʌ, æ/, which were then used as speech materials for an acoustical analysis. The procedure used in that version of the SLM for categorizing L2 sounds (pp. 36-42) led to the classification of /ɪ/ as *identical*, /i, ɒ, u, ʌ/ as *similar*, and /æ/ as *new*. For the two "similar" vowels /ɒ/ and /ʌ/, significant differences were found between F1 values of English speakers and those of the two groups of Dutch speakers. No other significant differences were found for F1 values, and none were found for F2 values. No significant differences were found between the two groups of Dutch speakers (pp. 77-78). Otherwise stated, the experienced Late L2 learners did not differ from inexperienced Late L2 learners to a greater extent for new L2 sounds than for similar L2 sounds, or, indeed, along any of the dimensions chosen for this experiment. And, while these late L2 learners did manage to produce two similar L2 vowels as approximations only (/ɒ/ and /ʌ/), they also produced two other similar L2 vowels (/i/ and /u/) which did not differ significantly from L2 normal specifications.[23]

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[23] As a first part of this study, the vowel tokens of three groups of 16 Dutch speakers were submitted for identification to groups of American English and British English listeners. In light of the near total success that substitution of an L1 sound can garner in this type of test (see pp. 30-31, above), the results of this investigation are accorded less importance in the present discussion. In addition, trends are somewhat obscured by differences in identifications given by British and American listeners. Still, as an indication of the fact that no clearer support is to be found in these results, it should be noted that the overall percentage of correct identifications for the new vowel /æ/ as produced by Dutch

In two other studies which are claimed to offer some support to the similar-new distinction of the SLM, the results are no clearer. In one of these, Major (1987) investigated the pronunciation of English /ɛ/ and /æ/ by speakers of Brazilian Portuguese, and found that, while global accent ratings correlated positively with accuracy of the new vowel /æ/, they correlated negatively with accuracy of the similar vowel /ɛ/—that is, as learners' overall pronunciation improved, their productions of /ɛ/ actually deteriorated.[24] The apparent support offered by these results to the similar-new distinction must be considered in light of the results from yet another investigation, which is considered immediately below.

In a third study held to offer empirical support to the similar-new distinction of the SLM, Bohn and Flege (1992) submitted the productions of English /i, ɪ, ɛ, æ/ by inexperienced and experienced German-speaking learners to acoustic analysis of spectral and durational characteristics and to the intelligibility judgements of native speakers of English. In the intelligibility test, the two similar vowels /i, ɪ/, as produced by the learners, were identified with nearly 100% accuracy, while the similar vowel /ɛ/ and

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learners was higher than that for the similar vowel /ʌ/, but lower than those for the similar vowels /i/, /u/, and /ɒ/.

24 Major (1987: 78) suggests the possibility that this apparent deterioration in the pronunciation of /ɛ/ may be an example of "backsliding", but adds that one can make firm conclusions with regard to that phenomenon only on the basis of results from longitudinal studies.

the new vowel /æ/ of the learners were identified significantly less accurately than those of the native English speakers (p. 148). To summarize the results of the acoustic analysis (of both spectral and durational properties), one can conclude that subjects in the two German groups succeeded in producing only approximations of the similar English vowels /i, ɪ/ (pp. 141-143) and of the new vowel /æ/ (pp. 143-146) and that the two groups did not differ significantly from each other. On the other hand, with respect to the similar vowel /ɛ/, the experienced learners managed only an approximation, while the inexperienced group produced an acoustically authentic English vowel (pp. 143-146).

This final result from Bohn and Flege (1992) parallels the findings of Major (1987), in that accuracy of production of the English vowel /ɛ/ apparently diminishes with increased L2 learning,[25] and both studies are claimed to offer support for the SLM's similar-new distinction. Nonetheless, considering the results of the two studies together, one notes that the new vowel /æ/ is not found to distinguish itself from two similar vowels /i, ɪ/, where production is concerned, or from /ɛ/, where intelligibility is concerned; on the other hand, the similar vowel /ɛ/ is shown to be distinct

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25 Bohn and Flege (1992: 153) and Major (1987: 79) account for this phenomenon in terms of the shifting of an existing category (/ɛ/) under pressure from a nascent one (/æ/).

from the other two similar vowels. On this latter topic, Bohn and Flege (1992: 154) state that: "the present results indicate that English /ɛ/ is a problematic vowel for L1 Germans, even though it is not recognized as such in textbooks comparing English and German vowels."[26] Along these lines, one might note as well that the relatively greater difficulty of /ɛ/, as compared with that of /i/ and /ɪ/, has not been recognized by the SLM either.

Some of the apparently least equivocal support for the similar-new distinction comes from Flege's (1987) investigation of the pronunciation of the French high rounded vowels by English-speaking learners. The author analyzed the formant frequencies of the "new" French vowel /y/ and the "similar" vowel /u/ as spoken by English-speaking learners of French. Out of three groups of native English subjects varying according to L2 experience, only the most experienced group showed evidence of approximating F2 norms for French /u/; while these learners had moved in the direction of French specifications, their mean F2 value (1508 Hz) was still substantially higher than the L2 norm (1196 Hz). On the other hand, for French /y/, only

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26 J. Ohala has noted (in personal communication) that /ɛ/ is usually slightly diphthongized in North American English. He has suggested that the observed difficulty associated with this vowel may have its source in the lack of diphthongization, or different kind of diphthongization, in its German counterpart.

the F2 values of the least experienced learners differed significantly from the French norm. On the basis of these results, the author concludes:

> ... the results presented here indicated that adults are capable of learning to produce new phones in an L2, and of modifying their previously established patterns of articulation when producing similar L2 phones. It appears that the mechanism of equivalence classification leads them to identify acoustically different phones in L1 and L2 as belonging to the same category. This may ultimately prevent them from producing similar but not new phones authentically. (p. 62)

While the results given here might be interpreted to lend support to the notion that difficulty associated with an L2 sound increases as phonetic distance from an L1 counterpart decreases,[27] they do not forcibly lead in that direction. The salient difference between these learners' production of French /y/ and /u/ might well have been something other than a *similar-new* contrast.

Rochet (1995) uses perceptual data to provide an alternative explanation of the English learners' poorer production of French /u/ than of /y/. In this article (pp. 381-387), the author argues against the retention of the similar-new distinction, on the grounds of the inadequacy of the methods used to classify a given sound as either similar or new. In addition, he challenges the validity of a fundamental assumption on which the distinction rests—

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[27] Note, however, that this investigation treats only a single new vowel and a single similar vowel. As was the case with Major's (1987) study, if more similar vowels had been included, the results might have been more equivocal.

specifically, in positing the possibility of the existence of a "new" vowel sound, one assumes the existence of uncommitted phonetic space within a learner's vowel inventory. In one of the investigations reported in Rochet's study, native speakers of European French, Brazilian Portuguese and Canadian English categorized synthetic stimuli ranging along an /i/ to /u/ continuum. In spite of the relatively impoverished nature of both the English and Portuguese high vowel inventories (both containing only two high vowels, as compared to the three of French), his results showed that, from a perceptual point of view, there are no gaps or unassigned sectors in the /i/-to-/u/ continuum in either language. Furthermore, comparing production data from English speakers and perception data from French listeners, Rochet (p. 380) concludes: "English /u/ being characterized by higher F2 values than its French counterpart, its realizations cover a range which straddles the French /y/ and /u/ categories." Further on (p. 384), he states the following:

> If ... we used as our starting point a description based on accurate acoustic information ..., we would be just as likely to conclude that French /y/ is similar to the vowel found in the English word *two*, whereas the vowel of French *tout* is a vowel not encountered in English, i.e., that French /y/ is to be viewed as a "similar" vowel for anglophones, and French /u/ as a "new" vowel.

On the basis of the above, with reference to the findings of Flege and Hillenbrand (1984),[28] Rochet (1995: 384) notes that it is quite reasonable to conclude that "American speakers had difficulty with the 'new' sound (/u/) and not with the 'similar' sound (/y/)"—i.e., that what was observed in the learners' treatment of these two sounds was precisely the opposite of what the SLM predicts.[29]

Recall, then, as has been noted above, that Flege (1995: 10) cites four studies whose results "have supported the hypothesis that new vowels will be produced better than similar L2 vowels by inexperienced late learners, but have offered only limited support for the claim that new vowels can be mastered by experienced late learners." The preceding discussion has attempted to show that, to date, empirical evidence fails to support either of the claims. With regard to the former hypothesis, some similar vowels have been shown to be produced *more* accurately than some new vowels; and with regard to the latter, where learners have been shown to have mastered an L2 vowel, the classification of that vowel as new has been seriously challenged.

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28 Flege and Hillenbrand (1984) describe a study similar to that of Flege (1987), with similar results and conclusions.

29 Rochet's arguments were directed to an earlier version of the SLM, in which "similar" and "new" sounds were seen as members of discrete, qualitatively different categories. Still, while this model has been abandoned in favour of a slightly-different-to-very-different continuum (see pp. 29-30, above), the importance of his argument is not diminished.

In light of the above, it becomes evident that the claim concerning the relationship between distance and difficulty has not found sufficient support to make it tenable. Moreover, Rochet's (1995) challenges threaten the hypothesis at its very foundation. And even if, in the future, solid support were to be found, this aspect of SLM would not offer valuable help to the pronunciation teacher—at least not immediately. As an illustration of this point, if it should be found that late learners do indeed fail to establish categories for similar L2 sounds, such knowledge would not be useful to the teacher until subsequent research revealed whether pronunciation training could alter this scenario (in which case the sound in question would require increased attention in the correction curriculum), or whether fossilization is early and inevitable (in which case the sound would be accorded decreased attention). Similar problems would be posed with regard to L2 sounds which are phonetically distant from any L1 equivalents. In short, seen in the best light, the hypothesized difficulty-distance relationship is not likely to offer much help in the pedagogy of phonetic correction for quite some time; seen in the worst light, it is not likely ever to do so.

The above is not to be taken to mean that the Speech Learning Model and the many investigative endeavours it has fostered have been unproductive. On the contrary, they have made some very important

revelations, particularly with regard to the effect of L2 learning on L1 phonetic values (Flege, 1987) and the changes in the efficacy of L2 speech learning which occur as a function of age (Flege, 1995). In addition, studies inspired by the SLM over the course of the last decade and a half have deepened our understanding of the phonological shape of learners' interlanguage and, together, these writings constitute a valuable manual on methods of research into L2 perception and production.

More importantly for the central interest of the present study, it is judged here that the greatest value of the Speech Learning Model lies in its explanation of phonetic difficulty in terms of categorical perception or equivalence classification. Research inspired by the model has yielded findings which suggest that non-functional phonetic differences in sounds remain auditorily accessible to adults.[30] Other studies have demonstrated the

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[30] For example, in Flege's (1984) investigation of accent detection, native speakers of American English and native speakers of French read English phrases such as *two little dogs*. Recordings of these phrases were played to American subjects, who were asked to identify them as having been spoken by a native or non-native speaker. In successive experiments, progressively smaller portions of those phrases were presented to subjects until, in the final one, they heard only a 30-ms segment immediately following the end of the closure of phrase-initial /t/. Even from this minuscule portion of a speech sample, subjects were able to identify foreign accent with a good degree of reliability. On the basis of this, the author concluded that the learner "who maintains [L1] patterns of segmental articulation in [L2] words does not necessarily do so because [L1-L2] phonetic differences are auditorily inaccessible" (p. 704).

reality of equivalence classification,[31] as well as the success of the notion in accounting for certain accented pronunciations, which fail to find explanation in terms of articulatory difficulty.[32] Taken together, such findings stand as a genuine alternative to the notion of the perceptual "sieve", which filters out sound characteristics that play no functional role in L1 phonology (Trubetzkoy, 1939: 51-52). More investigation of this phenomenon of categorical perception, of the kind conducted by Rochet (1995) is needed to define the vowel inventories of different languages from a perceptual point of view. Such knowledge is a necessary part of the complete grammar of any language. In addition, it can help linguists sort out language-specific patterns from universals.[33] Finally, of anything that the SLM has to offer to pronunciation teachers, it is information surrounding this notion of equivalence classification that is likely to offer the most important benefits to L2 pronunciation teachers.[34]

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31 For example, as was indicated above, Flege (1991) asked native speakers of Spanish to classify tokens of English *beat, bit, bet,* and *bat* according to whether they contained the Spanish vowels *i, e, a, o,* or *u,* or a vowel that was not Spanish. As experience with English increased, subjects labelled English /ɪ/ more often as "not Spanish", and less often as Spanish "i". On the other hand, all Spanish subjects, regardless of experience, continued to categorize English /æ/ as Spanish "a".

32 See, for example, Rochet (1995).

33 In this regard, see § 2.3.2 of Rochet (1995) for a discussion of the "natural perceptual boundary" between /i/ and /y/.

34 In light of what has been discussed so far, the notion of equivalence classification, taken together with findings relating to the auditory accessibility of non-functional (in L1) phonetic variation, offers at least some hope to the pronunciation teacher. All language

RESEARCH ON PERCEPTION

Over the course of the last two decades, the number of investigations into speech perception has grown almost geometrically. The multiplication of new theories concerning how speech signals are received and processed can be explained in large part, no doubt, by technological advances which have enabled the testing of their claims. An illustration of this can be found in the investigation of Sapon and Carroll (1958), where researchers attempted to test subjects on series of items containing a "key word" and another word differing from the key in a single "crucial" phonetic element. On the question of acoustic controls of this crucial element, these authors state that other variations were not "auditorily apparent" to the investigators and that sound spectrograms of the signals showed "close concordance ... between the non-crucial phonetic elements in terms of duration, voicing, and other relevant phonetic dimensions" (p. 70, note 2). With the general availability of the digital speech synthesizer[35] and of the digital speech processor, such controls

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instructors are familiar with the situation in which, on presenting minimal pairs such as /vu/ and /vy/ for illustration, they hear a student say: "I can't hear the difference." It now seems safe to interpret this to mean: "I can't hear a *meaningful* difference." Coupled with recent revelations concerning auditory training (discussed in "Research on Perception", immediately following), this hope is transformed into real help.

35 The use of synthetic speech has been criticized for leaving out important high-frequency components of the speech signal (see, for example, Elman et al., 1977). Still, it is the interplay of results from experiments using synthetic speech and those using natural

are effected with a much smaller expenditure of time and with far more reliable results. Since theoretical claims are now much more easily tested, it is not surprising to note the multiplication of theories of perception (and spirited discussion) which has occurred over recent years in L1 speech research.[36] These theories, in turn, will probably foster some important cross-language and L2 research in the future.

Thus far, while a few such investigations have been made, no firm revelations have appeared. As an illustration of this, with regard to cross-language findings, Strange et al. (1976) investigated the perception of North American English vowels by native speakers and found that the /CVC/ environment provides optimal conditions for vowel identification. These researchers concluded that "no single, temporal cross section of a syllable conveys as much vowel information to a perceiver as is given in the dynamic contour of the formants [i.e., in the transitions from and to surrounding consonants]" (p. 221). Using these and other related findings (e.g., Gottfried and Strange, 1980; Strange et al., 1983) as a point of departure, Gottfried (1984) found that French listeners identified vowels most accurately in isolation and in /tV/ context. He concluded that "although a 'target' theory

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speech (as is, or digitally altered) which will eventually yield clues concerning which elements of a signal are perceptually important and how they are important.

36 See, for example, Strange (1989) and Nearey (1992).

of vowel perception is inadequate to explain American English vowel identification and discrimination, such a theory might account for French vowel perception" (p. 110). Even before the publication of this study, however, Diehl et al. (1981) had asked subjects to respond to English vowel stimuli in a variety of ways, and found that the /CVC/ environment yielded an advantage for only one of the tasks. On the basis of these findings, the authors suggested that the apparently optimal conditions offered by the consonantal environment in the study of Strange et al. (1976) were due to artifacts related to stimulus-response compatibility and memory load, rather than to real perceptual benefits. Approaching the issue from a different direction, Andruski and Nearey (1992) conducted experiments with speakers of Western Canadian English as subjects, and concluded that the perceptually salient information contained in the temporal margins of vowels is "vowel-inherent spectral change", rather than consonant-to-vowel transition. Taking together the findings of these studies, then, the most that one can conclude is that perceptual differences between speakers of French and English may exist, but if that is the case, the precise shape of those differences has not yet been revealed.

Studies in L2 perception—apart from those which have emerged directly from the Speech Learning Model—appear to offer no clearer findings. As an

example, one might note the investigation of the perception of French /o/ and /ɔ/ conducted by Gottfried and Beddor (1988), in which a synthesized /kot/-to-/kɔt/ matrix was constructed. Along one dimension of the matrix, the tokens varied in 10 spectral steps; the other dimension held three different values for vowel duration. Tokens from this matrix were presented to native speakers of French as well as to native speakers of American English—one group of the latter had studied French, while the other had not. Findings showed that vowel duration was perceptually relevant among both groups of English-speaking listeners, but not among the French listeners.

The shape and the results of this study parallel those of the investigation of the English /æ/-/ɛ/ contrast conducted by Bohn and Flege (1990). Here, tokens from an 11 × 3 (frequency × duration) synthetic matrix were categorized by native speakers of English and by two groups of German-speaking learners varying in L2 experience. In a subsequent investigation, Bohn (1995) reports findings from a similar approach to the study of the English /i/-/ɪ/ contrast among native speakers of Spanish and Mandarin. Once again, in all cases, native speakers were found to rely on duration differences in categorizing the tokens to a far lesser degree than learners. Taking together the findings from the above-mentioned studies and others, Bohn (1995: 19) advances the following explanation:

> ... whenever spectral differences are insufficient to differentiate vowel contrasts because previous linguistic experience did not sensitize listeners to these spectral differences, duration differences will be used to differentiate the non-native vowel contrast.

As an alternative to this explanation, however, this same author notes the possibility that the results are an artifact of experimental design—that is, in the studies reported here, vowel duration was varied in only three equal steps, while the formant frequency continua contained either 10 or 11 eleven different values. As Bohn notes here (p. 25), "This conspicuous parallel might lead one to suspect that non-native listeners prefer to attend to the least varying dimension in perceptually differentiating non-native contrasts." In this light, then, the apparently general recourse, among L2 learners, to durational differences in preference to spectral differences must not be regarded without a degree of skepticism.

In contrast to results obtained from cross-language studies and from studies in L2 perception, recent revelations from investigations of the effectiveness of perceptual training offer some real help to the L2 pronunciation instructor. Early experiments on the effect of perceptual training on auditory discrimination and on production appeared to offer less hope; they tend to show either poor results (Catford and Pisoni, 1970) or mixed results (Pimsleur, 1963; Henning, 1966; Mueller and Niedzielski, 1968).

And, as recently as the late '70s, after reviewing a number of investigations of the effectiveness of perceptual training, Strange and Jenkins (1978: 153) were led to conclude that "significant modification of phonetic perception is not easily obtained by simple laboratory training techniques". Still, even at this time, the picture hardly seemed as bleak as these two authors portrayed it to be. If perceptual training was not found to solve all the problems of L2 phonetic difficulty, it was nonetheless shown to foster some improvement.

One issue which arises from these early studies and which is worthy of note concerns the use of perceptual training in L1-L2 contrasts. In one of two experiments conducted by Pimsleur (1963), subjects' attention was focused on the pure vs. diphthongized vowel contrast between French (L2) and English (L1) near-equivalents, as in *chaud-show*, for example. After a listening-only session, subjects were asked to identify tokens as being representative of either American or French pronunciation; "Right-Wrong" feedback was provided after each response. Results showed that, with respect to the production of non-diphthongized French vowels, the experimental group, who had had discrimination training, was not better than the control group, who had had no such training. On the basis of these results, the author concluded that discrimination training was not effective for the pronunciation problem in question, since that difficulty involves a motor skill and, therefore,

must be corrected through practice in pronunciation rather than discrimination. Having questioned the usefulness of classifying the speech of others as good or bad, he further suggests the following:

> We do not mean to imply that it is bad to make students aware of the difference between good and poor pronunciation, but merely that the expenditure of large amounts of time in this endeavor may be both unnecessary, since most students hear most such differences almost at once, and unprofitable in terms of the benefit to the student's own pronunciation. The time might better be spent in practicing pronunciation. (p. 202).

Two later experiments, however, present results which are in opposition to those of Pimsleur. In one of these, Henning (1966: 15) found that American subjects who had had discrimination training outperformed those who had not in production of "Unglided [French] Vowels". In the other study, Mueller and Niedzielski (1968: 413) found similar results with respect to the pronunciation of "[French] vowels which have a correlate sound in the English system: /e, a, o/".[37] Since these results were obtained through the use of perceptual training techniques which were apparently similar to those used by Pimsleur (1963),[38] the reason for their disparity remains unclear. At any rate, without broaching the question of how much time should be allotted

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[37] While the problem of diphthongization is not mentioned specifically here, it might be assumed that it constituted a substantial part of correctness with respect to the vowels /e/ and /o/.

[38] For descriptions of the procedures used, see Henning (1966: 10), and Mueller and Niedzielski (1968: 412).

to the practice, one is led to conclude, in light of the findings of the two more recent of these studies, that the exercise of identifying speech tokens as representative of L1 or L2 pronunciation is indeed a worthwhile one.[39]

More recently, a number of studies, focusing on voicing contrasts in consonants, have yielded quite unequivocal results. Among these are two experiments conducted by Pisoni and his colleagues, in which subjects were given training aimed at helping them to form new categories of stop consonants on the basis of different values of voice-onset timing (VOT). In the first of these, Pisoni et al., (1982) found that "naive subjects can perceive an additional perceptual contrast easily in the laboratory after a short training period" (p. 308). In the second (McClaskey et al., 1983), subjects were found to have generalized such improvement in category formation to a new place of articulation on which they had not been given training.

Commenting on these two studies, and others in which perceptual training was found to lead subjects to form new phonetic categories, Jamieson and Morosan (1986: 206) stated the following:

> Most of the preceding studies did not examine whether training transferred to natural speech sounds. While none of the studies found successful transfer to natural speech, it is clear that, within the

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[39] This judgement is made equally on the basis of L2 classroom experience. The practitioner knows very well that, while some L1-L2 contrasts may indeed be detected by learners "almost at once", others are perceptually much more elusive.

> restricted set of synthesized or edited tokens, training can produce clear changes in the categorization and discrimination of non-native speech contrasts by adult listeners."

With reference to earlier studies in which perceptual training was not shown to be successful, these authors suggest that at least some of the failures might be attributable to deficiencies in training methods, and they recommend adherence to three principles of perceptual training:

> (1) *Acoustic context*—Training should ensure that the relevant speech cues are presented in an acoustic context that is appropriate for normal speech, rather than in isolation. (2) *Identification training*—Since the desired outcome is to improve the listener's ability to classify speech sounds into the categories that are relevant for the new language, the listener's training task should involve identification (with feedback). Practice at discrimination, on the other hand, is likely to have the undesirable effect of enhancing sensitivity to within-category acoustic differences. (3) *Acoustic uncertainty*—Training should begin by focusing attention on the critically relevant cues and then introduce a range of acoustic variability in the signals. (p. 207)

Expanding on this third principle (p. 208), they describe the technique of "perceptual fading"[40] in which subjects are introduced first to maximally differentiated stimuli and, as training progresses, the magnitude of contrast is reduced. Using this procedure, these researchers attempted to train Canadian francophone adults in the English /θ/-/ð/ contrast, and found that after 90 minutes of training, identification performance of subjects improved not only

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[40] Jamieson and Morosan credit Terrace (1963) with the introduction of this technique.

with the synthetic stimuli used in the training, but also with natural speech tokens which had not been heard before.

In a follow-up study to the one discussed above, these same authors (Jamieson and Morosan, 1989) repeated that experiment, replacing the perceptual fading technique with training in the contrast between a single synthetic "prototype" of each of the two fricatives. Comparing the results from this investigation with those of the former, they found that 40 minutes of prototype training had been as effective as training with the fading technique for identification of natural speech tokens and for the synthesized tokens having contrasts equal to and greater than the prototypes. On the other hand, prototype training was shown to be less effective than fading for the identification of synthetic tokens having finer contrasts.

Recently, Rochet (1995) used perceptual fading to train native speakers of Mandarin Chinese in the voicing contrasts of French stop consonants. Subjects were trained on synthetic tokens of bilabial consonant plus /u/ from a continuum varying in VOT. This researcher found that, after 180 minutes of perceptual training, subjects became more French-like in their perception of the /b/-/p/ contrast before the vowel /u/ (synthetic signals), on which they had been trained, as well as in their perception of the same consonants before other vowels, and of the voicing distinction between dental and velar

consonants before /u/. Effect of training also transferred to perception of natural stimuli for voiceless, but not for voiced consonants. An additional dimension of this study is that it looked for changes in production which might be observed to follow perceptual training. Here it was found that subjects improved in their pronunciation of both voiced and voiceless French consonants, however, in the former case, that improvement narrowly failed to reach significance. Rochet found as well that training with word-initial stop consonants did not produce improvement in either perception or production of intervocalic stops. He explained this last result as a product of the fact that voiced-voiceless contrasts in intervocalic position rest on differences in closure duration, in duration of preceding vowels and on presence or absence of F0 during closure (p. 397). In this light, it is hardly surprising that training in VOT duration alone failed to effect improvement with respect to consonants in this environment. Finally, although this author stressed the need for investigations into the durability of effects of such short-term training (p. 398), he has also noted preliminary results of Pisoni and colleagues showing retention after a six-month lapse.[41]

Taken together, the results of these studies in perceptual training appear to point to some meaningful revelations for the teacher of L2 pronunciation.

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41 B. Rochet, personal communication.

The first deals with the source of phonetic difficulty, and is stated by Rochet (1995: 397) as follows:

> Although some L2 sounds may prove difficult to articulate (and some more so than others), it appears that most accented pronunciations that are viewed as resulting from articulatory difficulties may be instead the consequence of their having been assigned to an L1 sound category.

The second revelation lies in the findings, noted above, that short periods of laboratory training can improve both perception and production of L2 sounds. Finally, insofar as perceptual training is found to foster improvement in both perception and production, it is to be preferred to production training, since accurate identification of L2 sounds is a goal of the pronunciation course in its own right (for understanding of messages), and it is easier to administer than production training.[42] Taken together, these points provide sufficient motivation for the inclusion of such training in the curricula of L2 pronunciation courses. As it appears now, the focus should be on identification or categorization tasks (involving both L1-L2 contrasts and phone-to-phone contrasts within L2), as opposed to same-different discrimination tasks. Moreover, fading techniques have been shown to be

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42 While production training can be given only by a trained professional, who evaluates phonetic output and suggests articulatory modifications to effect improvements, perceptual training can be administered by computer. This means that, given access to a laboratory, learners can make phonetic progress on their own, as their time permits. In addition, once perceptual difficulties have been overcome, time can be spent effectively in production practice, since, at that point, learners are able to evaluate their own output.

highly effective in training learners on durational aspects of consonantal contrasts, and the practice should be adopted in pronunciation courses for the teaching of such oppositions. Further research is required to determine whether this approach offers similar benefits with respect to other dimensions of phonetic difference. For the moment, in the absence of such evidence, it remains clear that less complex and less time-consuming training, using synthesized prototypes and natural signals, offers substantial benefits, and needs to be included in the curriculum as a part of the approach to all other topics in which accuracy of phonetic shape may be an issue.[43]

Still, as is the case with any recommendation emerging from notions requiring broader empirical validation, that given here is a prescription for one pedagogical approach, but not a proscription for another; that is, it is recommended here that perceptual training *be added to*, rather than *replace*, articulatory instruction. As has been noted, the recent successes found to result from perceptual training have focused on consonantal contrasts, and studies conducted earlier, dealing with L2 vowels, have shown mixed results.

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[43] Examples of topics from the curriculum in French pronunciation in which accurate categorization is not an issue are those dealing with the retention and deletion of the unstable *e*, and with obligatory, optional, and proscribed liaison. These topics deal with the question of *whether* to pronounce, rather than *how* to pronounce. Of course, in those instances where pronunciation is required, accurate form—as well as perceptual training—becomes important. In the case of liaison, for example, consonants must be produced with appropriate voicing characteristics. Still, consonant voicing characteristics constitute a general difficulty which must be treated elsewhere in the curriculum.

It is not known, at this point, just how far the benefits of perceptual training extend. The ultimate goal in L2 pronunciation instruction, of course, is to foster native-like performance in both perception and production. And it appears that articulatory instruction can lead learners to pronounce accurately, even if that improvement is not accompanied by equal improvement in perception.[44] Approaches which foster the best performance in each of perception and production—separately, if necessary—must not be abandoned. Until it is found, then, that perceptual training alone is at least as effective as perceptual training *with* articulatory instruction in *both* facets of the endeavour, it is too early to dispense with the latter.[45]

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44 See, for example, Brière (1966), and Sheldon and Strange, (1982).

45 Classroom instructors—the best ones, at least, and those who write manuals are not excluded—are an eclectic lot. Illustrative in this regard is Rochet's (1990: 109-110) approach to the teaching of production of non-aspirated voiceless French stops. This author offers three strategies for English-speaking learners to adopt in the attempt to master this feature; one of them involves placing syllable-initial consonants into syllable-final position (e.g., to pronounce *la patrie*, normally analyzed as /la-pa-tri/, as [lap-at-ri]), where in L1, stops are not aspirated. In a footnote relating to this recommendation (p. 110, note 45), Rochet offers the following comment:

> Note that this is in contradiction with the syllabic principles generally accepted as governing the French language .... The cut advocated here must be viewed as a practical device only, with no bearing on the theoretical issue of syllabification. In favour of its retention, it must be said that this particular device seems to be one of the most successful in learning to pronounce non-aspirated voiceless stops.

In spite of the consequent breach of important theoretical principles, the recommendation is included; and it is unlikely to be excluded before another approach is shown to be more effective. The point to be taken from this is that the first theory which governs the approach of practitioners—and justifiedly so—is that it is good to use what has been shown to work.

Perusal of the pronunciation manuals consulted for this review shows that, while auditory discrimination practice is given a place in the curriculum for phonetic correction, it is often accorded less importance, or administered less effectively, than one might like to see. Dansereau's (1990) programme includes a total of seven auditory exercises, all requiring identification of L2 vowels contained in one-word stimuli; while there are exercises focusing on L1-L2 contrasts (e.g., of English-French near equivalents, such as *low-l'eau*), these are in a listen-repeat format.[46] Carduner and Hagiwara (1982) include about twice as many auditory exercises, and Valdman (1993) has even more; these involve both identification of French sounds and classification of words as either French or English on the basis of varying features within segments treated in the lesson in question. It was noted earlier that one of the programmes consulted here includes virtually no phonetic description (Champagne-Muzar et al., 1986) and, consequently, relies solely on recorded exercises. In this curriculum, well more than half of the total of ten hours of exercises is devoted to listening tasks; however more than half of that part deals with sensitization to prosodic patterns.[47] In what remains—those

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46 The practice of asking learners to repeat L1-L2 contrasts may heighten sensitivity to articulatory contrasts and may thus have a degree of merit. However, the contention here is that, before being asked to repeat, learners should be given some exercises in which the sole focus is on increasing sensitivity to the perceptual contrasts.

47 There is no quarrel here with the emphasis placed on rhythm and intonation. What is criticized is the impoverished treatment accorded to the perception of segments.

exercises dealing with perception of segments—many exercises ask learners to indicate whether a polysyllabic utterance does or does not contain a given sound. While there are a few two-choice categorization tasks, there are no English-French contrastive exercises. In the total curriculum, then, very little attention is given to focusing narrowly on the phonetic shape of segments.

Rochet (1994: 180-181) emphasizes the importance of immediate feedback in the training of perception. In addition, he notes that, for correction of erroneous responses to be meaningful, it must offer more than a simple indication of error; specifically, it is necessary that learners be able to replay easily and as often as they wish the stimulus they heard together with a token containing the sound which they chose in their response. The computer is uniquely adaptable to offering both immediate and meaningful error correction. In all the programmes considered here, feedback is less immediate than would be desirable.[48] In none are the benefits of digital technology put to use. Such is the extent of perceptual training provided by programmes currently in widespread use in North America.[49] Clearly, there

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48 In Carduner and Hagiwara (1982) and Dansereau (1990), feedback is provided in the form of a printed answer key located on a different page of the manual. In Valdman's (1993) programme, no feedback is given either in print or on tape. Presumably, then, it is to be provided by the instructor.

49 Of the five programmes considered here, Rochet (1990) accords the greatest importance to perceptual training—at least with respect to the perception of segments. The manual contains a good number of perceptual exercises of the type noted in the discussion of the other programmes; in addition to these, immediate feedback and fading techniques are

is a need for the development of a commercially-available programme or set of ancillary materials which make use of digital technology to provide immediate feedback to responses and which incorporate fading techniques into the perceptual training component of the L2 pronunciation course.

CONTRASTIVE ANALYSIS

The ultimate goal of L2 phonological research—and the ultimate need of teachers—is, of course, the formulation of a complete and adequate theory of L2 pronunciation learning. The stipulation of *adequacy* requires that such a theory account for all phonetic behaviour observed to occur in L2 learners and, in addition, that it do so within the framework of an adequate theory of language in general, which would include, of course, an account of L1 speech learning. Finally, it must be buttressed by a substantial amount of empirical support in order that it be shown to be tenable. In light of all the preceding discussion, it is judged here that these requirements are unlikely to be met in the near future.

For the time being, in the absence of an adequate theory of L2 speech learning, practitioners could benefit from one which is less than adequate, but

currently in use within the curriculum, but are not noted in the manual (B. L. Rochet, personal communication). Unfortunately, this programme has been developed for intramural use, and is not currently available to the wider L2 teaching community.

which nevertheless accounts for a good deal of observed phonetic behaviour in learners. It is judged here that Flege's (e.g., 1995) Speech Learning Model, modified—and weakened—in some of its dimensions, does satisfy these relaxed requirements. To summarize this theory briefly, at its heart is the hypothesis that foreign accent has its primary source in perception through the vehicle of "equivalence classification"—the process according to which perceptibly different tokens are judged to be functionally equivalent. As learners hear L2 sounds, they judge them to be members of already-established L1 categories; phonetic differences in those L2 sounds are disregarded as having no functional relevance. When learners reproduce the L2 sounds, they do so on the basis of existing L1 "phonetic realization rules", and are heard to substitute L1 segments for the intended L2 sounds—at least in beginning stages of learning.

An important addition to this model is discussed below. To be noted at this point are two deletions from the SLM, as it has been outlined by Flege (1995). The first of these is the abandonment of the notion of the inverse relationship between phonetic difficulty and distance between L2 sounds and L1 counterparts. In line with conclusions reached earlier (pp. 39-40), this is motivated both by the lack of empirical support for such a relationship and by the serious problems associated with the determination of phonetic

distance, as discussed by Rochet (1995). It is recognized, of course, that the deletion of this aspect of the SLM diminishes substantially the theory's adequacy as a model of L2 speech learning—robs it of its claim to be able to predict relative phonetic difficulty. Nonetheless, it is judged here that the theory is effectively poorer, rather than richer, for the inclusion of an unsubstantiated hypothesis. Furthermore, from the point of view of application, an obvious gap in the theory is far less dangerous than an uncorroborated claim.

As a consequence of the abandonment of the hypothesis concerning a difficulty-distance relationship, it becomes necessary to discard claims concerning how phonetic improvement occurs. Stated in another way, it becomes impossible to predict that progress in the direction of L2 norms will occur through adaptation or addition of realization rules for some sounds, but through formation of new phonetic categories for others. Further precision in the understanding of how speech learning occurs differently for some sounds than for others will have to emerge from future research.

What remains after the preceding deletions from the SLM, then, is a theory which has been considerably weakened. No longer an adequate model of L2 speech learning, it makes no proposals concerning hierarchies of difficulty, no claims with respect to which sounds can or cannot be mastered

by adult L2 learners. It is not posited here that articulatory difficulty plays no role in the phenomenon of foreign accent, but that it plays a minor role.[50] Finally, the theory stops short of attempting to account for all learner forms, and recognizes that there will be some errors which lie outside of the region between L1 and L2 norms and which, consequently, must find explanations elsewhere.[51] What is retained, however, is the prediction that, except for cases of no learning (simple L1-for-L2 sound substitutions) and total learning (conformity with L2 phonetic norms), *most* phonetic forms in learners' speech will lie between L1 and L2 norms.[52] If no longer a theory of second-language

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50 Recall, in this regard, Rochet's (1995: 397) note concerning the articulatory difficulty of "some L2 sounds". This "minor" role is not to be interpreted as an unimportant one. Indeed, it may be that articulatory difficulties, where they exist, are the most resistant to eradication. The claim here is that articulatory difficulty is important for only a small proportion of the phonetic changes which must be mastered in the course of L2 learning.

51 As an example of such errors, one might note that Flege and Eefting (1987) found some of their Dutch subjects with the best accents in English to "overshoot" the VOT norm for English /t/. There are also cases in which learners have been found to realize L2 sounds with values that diverge from those of L1 specifications, but *in the opposite direction* from L2 norms (e.g., Flege, 1980). It should be noted here that it is precisely this type of error that provided the impetus behind the introduction of the notion of Interlanguage.

52 This claim concerning the predictability of learners' forms presumes, of course, that interlingual identification patterns have already been established—i.e., that native speakers of the L1 in question have been found to equate a particular L2 sound with a particular L1 category. It is judged here that claims concerning the predictability of those equivalency patterns must be renounced—for the time being, at least. Rochet (1995) has *explained* the differing substitution patterns for French /y/ observed in native speakers of English and of Brazilian Portuguese; and these might indeed have been predictable. On the other hand, where other L1-L2 sound pairings are concerned, the ability to *predict* would require much more knowledge concerning relative weightings of spectral vs. durational differences, of steady-state vs. glide information, and the like. It is precisely in the attempt to explain such patterns that information concerning these weightings may be revealed.

learning, then, the model nevertheless remains a theoretical framework for accounting for the process of L1 *interference* in L2 phonetic learning.

It is clear from the above description that the theory posited here is quite simply a variation of the contrastive analysis hypothesis first proposed nearly half a century ago. One fundamental departure from that earlier model is the claim that the primary source of foreign accent is in perception, through the process of equivalence classification, rather than in articulatory difficulty. Another is the abandonment of the claim that a hierarchy of difficulty is predictable within the framework of the theory. Nonetheless, the approach is still quite clearly contrastive. In that light, it becomes necessary to address some of the criticisms which have been directed at that approach over the course of the intervening years.

As was noted in the introductory presentation of the theory, challenges to the validity of the Contrastive Analysis Hypothesis were based on both empirical and theoretical considerations. With respect to the former, it was found that the model failed to account for the shapes of all phonetic errors which learners were observed to make. In some cases, the magnitude of the failure of the hypothesis was simply exaggerated by scholars who were excessively zealous in their desire to discount the importance of L1 interference in L2 learning. Support for this assessment is found in some

striking inconsistencies found within the writings of such authors. For example, Tarone (1978) stated that "[L1] transfer is only a part and often a small part of the influence on interlanguage phonology" (p. 15) and that, because of this, "the CA hypothesis will always be rejected" (p. 21). In the same article, she cited studies in which CA could account for "a large number of the substitutions made" (p. 19) and "most of the results" (p. 17). No poorer performances on the part of the hypothesis were presented. The same kind of inconsistency is perhaps most striking in a comment by Brown (1980: 57): "...the saliency of interference from the first language does not imply that interference is the most relevant or most crucial factor in adult second language acquisition." Excessive zeal on the part of interlanguage scholars reveals itself as well in questionable analytical procedures. For example, Dulay and Burt (1974), after attempting to nullify the importance of L1 interference in second-language learning, classify a substantial portion of their own data under the rubric "interference-like goofs".[53]

The preceding paragraph stands as an illustration of the point that L1 interference was never, in fact, as unimportant, and that the magnitude of the failure of contrastive analysis was never as great, as some writers claimed.

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53 In order to avoid the pejorative connotations contained in the label "error", Dulay and Burt proposed the use of the term "goof". Subsequent writings in the field show that the new term never caught on.

Still, it must be acknowledged that a few, more solid, scholarly endeavours did reveal that contrastive analyis failed to predict a non-negligible number of observed learner errors in pronunciation (e.g., Ragusich, 1977). Still, the failure, in such cases, of analyses of L1 and L2 phonological systems to predict a portion of what was actually observed to occur can be explained in several different ways. In this regard, Corder (1973: 266) wrote the following:

> Of course, a predicted difficulty which does not show itself in errors in practice, or errors which are not predicted by the contrastive analysis do not (by any means) automatically disprove the theory. They may be the result of poor experimental method, i.e. they may derive from inadequate descriptive and comparative techniques. It would be a bold man who abandoned a theory on the basis of the analytic skills of both contrastive and error analysis as they have been developed up to the present time.

If the hypothesis is ill-conceived, then, of course, it must be discarded. On the other hand, if the flaw lies rather in the analyses out of which the predictions in question emerged, the solution lies not in the abandonment of the theory, but in the conducting of better analyses. In this thesis, the latter interpretation is adopted, and it is suggested below that there does indeed exist an approach which will produce better contrastive studies than those which were found wanting in the past. For the moment, let it suffice to note two key points. First, a huge body of research, most notably the work of J. E. Flege, attests to the salience—and *relevance*—of L1 interference in the learning

of L2 phonology.[54] Secondly, a theoretical framework which accounts for most, but not all, of what is observed to occur in learners' speech is inadequate, to be sure, but, for all that, is far from untenable.

Criticism aimed at the Contrastive Analysis Hypothesis out of theoretical considerations has taken different shapes. Dulay and Burt (1974: 97) questioned the model on the basis of its grounding in the no-longer-espoused tenets of behaviourist psychology, which saw learning as a process of habit formation, and second-language learning as a process of breaking those habits.[55] In response to this, let it suffice to note that the explanation of L1 interference in terms of equivalence classification severs CA's ties of dependency upon behaviourist psychology.

Wardhaugh's (1970: 127-128) primary criticism of the Contrastive Analysis Hypothesis dealt with the "strong" version (which claimed to be able to predict relative difficulty of L2 elements) and focused on its incompatibility with the generative-transformational theory in vogue at the time. At issue here was the notion that, according to this latter theory, all languages are essentially alike at the level of "deep structure"—so contrasts here are non-existent—and that what the language learner must learn is the

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54 Note also that an article sub-title such as "L1 Transfer Doesn't Tell it All" (Bohn: 1995) rests on the assumption that L1 transfer tells a very great deal.

55 For a similar argument, see Cox (1981).

set of rules which relate deep to surface structure. These rules, being unique—idiosyncratic—to each language, simply defy comparison. On the basis of his argument, this author concludes that:

> ... acceptance of that [generative-transformational] theory can fairly easily lead one to reject the idea that it is possible to make contrastive analyses, or, put less strongly, to reject the idea that generative-transformational theory has something to contribute to a theory of contrastive analysis, given the present state of the art. (p. 128)

In the course of the intervening years, Wardhaugh's conclusion here has lost a good deal of its import, since, with the evolution of linguistic theory, notions of deep structure have changed—and diverged—considerably.[56] The central theoretical problems associated with CA have thus paled over the years.

In contrast to the above, Wardhaugh (1970: 125) raised another, apparently secondary, issue, whose importance remains undiminished:

> Many a linguist has presented contrastive statements of the phonemic systems of two languages without asking whether it is possible to contrast the phonemic systems of two languages by procedures which attempt to relate an English *p* to a French *p*, because linguists have chosen to symbolize some not well-defined similarity between the two languages in the same way, in this case by the letter *p*, or because both *p*'s are associated with certain movements of the glottis and lips. The use of the similarity of the symbols is more deceiving than the use of the similarity of phonetic features. The latter may be justified to some extent in terms of what will be referred to later as the weak version of the hypothesis, but statements about a language *lacking* certain phonemes or two languages having the *same* phonemes are possibly even more dangerous than they are naive. Any such statements must

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[56] For an overview of these divergences, see Prideaux (1985: 15-33).

> ultimately rest on phonetic evidence .... As Weinreich (1953) points out, phonemes are not commensurable across languages; phones, individual sounds, are much more manageable, because they do have some connection with events in the world, in this case articulatory and acoustic events.

While Wardhaugh, in this passage, gave guarded consent to the use of phonetic features in establishing contrasts, that procedure had been rejected a few years earlier by Brière (1966: 795):

> ... any prediction of a hierarchy of difficulty of learning phonological categories must be based on descriptions of these categories in terms of exhaustive information at the phonetic level, rather than on descriptions solely in terms of distinctive features or allophonic membership of the phoneme classes.

Although there is divergence in the details, these two authors were in agreement concerning the notion that, ultimately, L1-L2 contrasts must be determined on the basis of phonetic reality. In spite of the fact that this idea was circulating at the time, some scholars persisted in the attempt to establish meaningful contrasts on the basis of abstract notions such as language-specific hierarchies of distinctive features (e.g., Ritchie, 1968) and markedness values of features (e.g., Eckman, 1977). Ultimately, their efforts did not prove successful.[57]

Some years later, K. J. Kohler (1981) published an article—treating the voiced-voiceless distinction of stop consonants in French and German—that

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57 For a discussion of these theories and a demonstration of their failures, see Rochet (1995: 387-388).

should be considered a landmark study in the area of contrastive phonology. In his introduction, this author raised two important principles for the conducting of contrastive studies. The first echoes the two comments cited immediately above:

> A truly structural approach, in which the values of units are determined by their mutual relations within one particular language, precludes a contrastive phonology within the same theoretical framework: the comparison only becomes feasible via absolute phonetic facts, not simply through their relative phonological structuring in each language. (p. 213)

The second principle extends the first to its logical conclusion:

> A descriptive account of the sound structure of a language can abstract from speaking and listening and may follow such principles as economy, simplicity, pattern congruity or integration of levels of description without considering speech performance, but the relation of phonological categories and units to the processes of articulation and perception has to be psychologically real in the case of a contrastive phonology that is to be applied to pronunciation teaching. Therefore, phonological elements can no longer be ambivalent with regard to production and perception as is common in descriptive phonologies. The articulatory and auditory repertoires in average users of a particular language transcend the limits determined by the native language to different degrees, and consequently their expansion leads to diverging difficulties .... (p.214)

By applying these principles to his own work, Kohler demonstrated just how much meaningful information is lost in labeling the difference between (French and German) / p, t, k/ on the one hand, and / b, d, g/ on the other, as ±*voice*. He showed as well that a contrastive analysis of the phonetic

substance of these sounds, which also looked directly at listeners' perceptual treatment of elements of that substance, accounted very well for their production by German-speaking learners of French, where analyses in terms of distinctive features had failed. In so doing, Kohler set a standard to be maintained thenceforth in the conducting of contrastive investigations.

Recently, in a study more germane to the focus of the present thesis, Rochet (1995) applied these same principles of research to his investigation of the perception and production of French /y/ by native speakers of North American English and of Brazilian Portuguese. Results from his production experiment corroborated previous observations that, when attempting to pronounce French /y/, English speakers often substitute an [u]-like vowel, while speakers of Portuguese pronounce an [i]-like vowel. Data from his perceptual task, involving categorization of synthetic stimuli varying along an F2 continuum, showed that, of those tokens classified as /y/ by French listeners, virtually all were labelled /u/ by English listeners and the vast majority were labelled /i/ by Brazilian listeners. Once again, contrasts based on consideration of perceptual behaviour and phonetic substance, succeeded in accounting for the differing production of the sound by these two groups of subjects, where those based on abstract phonological units and features had failed.

Recall as well (from pp. 52-53, above), that in his second experiment, Rochet found that perceptual training of Mandarin subjects with word-initial /p/ and /b/ before /u/ led to improvement in perception and production of the same consonants in other vocalic environments and of other stop consonants in the same environment, but did not produce improvement in either perception or production of intervocalic stops. In his discussion concerning this observation, he states the following:

> The results of Experiment 2 further suggest that subjects are learning L2 contrasts in a highly context-dependent manner, a finding that not only must be taken into account by L2 practitioners, but also is of great significance for our understanding of speech perception and for phonological theory. This, along with the results of Experiment 1 and other evidence from speech perception studies ...,[58] suggests that listeners do not encode phonetic contrasts in terms of some abstract context-independent unit like a phoneme. ... The focus on acoustic/gestural properties and context-sensitive variability constitutes a marked departure from previous attempts to deal with phonetic interference phenomena on the basis of idealized and impoverished representations of the speech signal. (p. 398)

What is advocated here is not only a logically necessary extension of the principle of basing L1-L2 contrastive descriptions on phonetic detail, but it is one whose importance has been empirically demonstrated: the quest to discover behaviourally relevant speech units is likely to be successful only if, until the contrary is shown to be true, a given sound in one environment is

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58 See, for example, Pisoni and Luce (1987).

assumed to be a different entity from what might be called the same sound in a different environment.

Rochet's discussion raises two additional points concerning the place of this phonetic detail within a theory of second-language acquisition. The first treats the question of how one might extract explanation from the detail:

> [Brière's (1966)] suggestion that we seek exhaustive information must have seemed daunting to those who were involved in a search for simpler, more elegant, and more economical descriptions, and it is true that exhaustive information must at some point be reduced to its essential or relevant components. Focusing on the mechanism of equivalence classification should allow us to extract from the exhaustive phonetic information we must never lose sight of, the relevant information which will make it possible to explain L1-for-L2 sound substitutions. (p. 389)

The point to be taken from this statement is that, in the absence of behaviourally relevant phonological units, there can be no understanding of L2 speech behaviour. The phoneme and the distinctive feature have not proved to be behaviourally relevant units.[59] The most efficient way to discover them is likely to be in the observation of perceptual behaviour.

Rochet's second point adds motivation for the principle of seeking out the details of phonetic substance:

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59 This is not to be interpreted as a denial of the behavioural relevance of the phoneme as a unit of *classification*; the fact that *boot* is heard to rhyme with *toot*, though the phonetic shapes of their vowels may differ substantially, attests to the reality of the phoneme in the minds of speakers of English. What is maintained here is that listeners make many decisions concerning the classification of sounds at a sub-phonemic level.

> Attention to phonetic detail should not ... be advocated only as a corrective step to fill in some information inadvertently left out while adhering to a well accepted theoretical framework. Detailed phonetic information must be sought because it is logically required and motivated by a model of second-language acquisition. (p. 398)

To echo Rochet's comment, then, the contention in this thesis is that *any* theory of second-language phonology must *begin* and *end* with the physical substance (acoustic, articulatory, and perceptual) of speech behaviour. A theory must end there, because it is the success of a model in accounting for such substance that ultimately reveals its value. It must begin there, because a model will find a greater measure of success if the details of what it must account for are known from the outset.

To summarize the discussion presented in this section, the Contrastive Analysis Hypothesis has been dismissed as untenable by some scholars on the basis of both theoretical and empirical considerations. It has been shown here that the solution to the problems noted from both standpoints lies in the adherence to the same methodological principle. Among the theoretical issues raised, the one which retains its importance after the passage of a good number of years is that L1-L2 contrastive descriptions are logically feasible only if they are based on observations of phonetic and behavioural substance. There is also good reason to believe that, with respect to the empirical problems raised, a modified contrastive model, which rests upon just such a

foundation, will find a significantly greater degree of success in accounting for learners' speech behaviour than former models did.

What is espoused in this thesis is a theory of first-language interference in the second-language speech learning of adults. It stops short of being a full model of L2 speech learning in that (1) it makes no attempt to account for the effects of non-linguistic variables in learning, such as individual strategies; and (2) it makes no attempt to predict the relative difficulty of the sounds of an L2 inventory. Notions which are central to this model are the following:

- *The primary source of second-language phonetic difficulty is first-language interference.* It follows from this that most L2 pronunciation errors can be accounted for through analysis of L1-L2 contrasts.
- *First-language interference operates primarily at the perceptual level through the process of equivalence classification.* According to this notion of equivalence classification, learners identify L2 sounds as members of existing L1 categories in spite of auditorily detectable differences between those sounds and their L1 counterparts. In producing L2 sounds, then, they do so via their L1 realization rules. These two processes together account for L1-for-L2 sound substitutions.
- *Improvement in perception of a second-language sound will generally be accompanied by improvement in production of that sound.* While some errors

may have their source in articulatory difficulty, and while these may be as persistent as those having their source in perception, it is claimed here that articulatory difficulty will be needed to account for a very small part of what is observed to occur in learner speech. In general, as new, L2-specific categories are formed by learners and, as the shape of these categories approximates more and more closely the shape of those of native speakers of L2, phonetic productions will approximate L2 norms more and more closely.

- *Learners' production of second-language sounds will lie between first- and second-language specifications for those sounds.* Beyond cases of L1 sound substitution (particularly prevalent in the early stages of learning) and attainment of L2 target norms, learners' realizations will lie within an acoustic space situated between L1 and L2 norms. Exceptions to this claim will be few in number, and will require explanation in terms of articulatory difficulty, individual strategies, or the like.
- *The validity of these claims with respect to explanation of learner speech behaviour can be established (or refuted) only through contrasts drawn between L1 and L2 phonetic detail.* This principle implies two imperatives: (1) that the phonetic characteristics of a given phoneme in one environment not be assumed to be the same as those of the same phoneme in a different

environment; and (2) that descriptions of production be founded on observations of production and descriptions of perception be founded on observations of perception.

This chapter has considered some of the literature emerging from the three major theoretical movements that have driven most of the research in second-language phonology over the course of the last fifty years. It has also looked at some studies of perception and perceptual training that have their sources in various theoretical frameworks. Considering all this investigative work in light of pedagogical manuals for courses in French pronunciation, and considering the manuals in light of the research, one must conclude that, in the eyes of practitioners, the most valuable work done in the field of applied phonology was the earliest work—that done within the framework of Contrastive Analysis. While this assessment has a considerable degree of accuracy, it would be inaccurate to conclude on that basis that the intervening years have been wasted. The field of L2 research has experienced—and is perhaps still experiencing—a period of theoretical struggle. Stepping back to observe its development over the course of these years from a little distance, one is drawn to the metaphor of a new-born foal struggling to find its legs. Progress has been slow, sometimes painful, and not always very direct, but there has been progress. The contention here is that the greatest step forward

has been the recognition of the perceptual basis of foreign accent. Furthermore, it has been suggested that current pedagogical practices need to be drawn into line with this realization, in order that learners be given the auditory training they require. Finally, this chapter has attempted to elaborate a theory of first-language interference which takes the notion of equivalence classification as a point of departure. If the focus is placed on perceptual contrasts, which have been established on the basis of observation of phonetic detail and of listeners' use of that detail, it is judged here that L1-L2 contrastive descriptions will account for substantially more of learners' speech than other contrastive descriptions have in the past.

COARTICULATION

INTRODUCTION

The phenomenon of *coarticulation* has been defined as "the simultaneous execution (or temporal overlapping) of articulatory gestures pertaining to different segments" and is held to account for the fact that "the speech signal is characterized by lack of acoustic invariance, a given linguistic unit (e.g. a phoneme or a word) having different acoustic manifestations in different contexts" (Suomi, 1987: 85). Closely associated with this process of coarticulation, particularly where variability in the spectral shape of vowels is concerned, is the notion of *undershoot*—the failure of formants to attain "ideal" target values (those manifested in a vowel uttered in isolation) when the vowel in question is pronounced in certain phonetic contexts. Among the first to use this latter term was Lindblom (1963), who concluded from his observation of Swedish vowels that degree of undershoot for a given vowel in a given context varies only as a function of timing—i.e., as vowel duration shortens, digression from ideal values increases, because there is insufficient time for articulators to reach ideal positions as they move from segment to

segment. Thus, both the terms "coarticulation" and "undershoot", as they are most commonly used in the literature, include notions of effect—phonetic variability as a function of context—*in addition to* a specification of cause—namely, articulatory constraints.

Still, not all of the variation in segments which occurs as a function of their differing contexts is necessarily attributable to articulatory constraints, as is noted by O'Shaughnessy (1990: 117): "Some of these effects may be due, at least in part, to learned phonological variation (to aid communication) rather than to mechanical coarticulation only." The present study attempts to investigate the variation in vowel timbre as a function of the consonantal context in which the segments in question occur. It stops short of attempting to explain the sources of that variation. In the interest of economy of expression, therefore, the terms *coarticulatory effects* and *undershoot* are used herein with less powerful meanings than are traditionally attributed to them. The reader is asked to keep in mind that, as they are used in this study, the terms are intended to refer broadly to "contextually-determined variation" (Ohala, 1993: 161), irrespective of the cause of that variation.[60]

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60 It might be noted here that Stevens et al. (1966: 130-131) also used the term "undershoot", even though their data indicated that there was more involved in contextually-induced spectral shifts than timing.

The phenomenon of coarticulation is not a recent revelation to students of speech.[61] As early as 1948, in his monograph entitled *Acoustic Phonetics*, Martin Joos included a chapter on "Segmentation and Decomposition", which is devoted, in part, to consideration of contextually-induced variation. Here, he noted, for example, the substantial acoustic difference between the /æ/ of /dæd/ and that of /gæg/ (pp. 105-106). Farther on, in speaking of the feasibility of dividing speech into acoustic segments (through the process of re-cutting), he added the following *caveat*:

> But this does not mean that each acoustic segment belongs to only one phonemic segment or even to only one phone. Instead, an acoustic segment generally exhibits features belonging to two or more phonemes, showing how illusory the acoustic resegmentation is ... . (p. 121)[62]

In spite of this early familiarity with the phenomenon, the roots of the systematic investigation of coarticulation appear to be traceable to 1963, when

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61 Ohala (1993: 156) traces the popularization of the term *coarticulation* to the year 1933.

62 The demonstration of the *acoustic* variability in vowels could not be done, of course, before the development of the sonagraph. Still, earlier linguists, relying only on acute hearing, were well aware that vowels do change as a function of their surroundings. Halle et al. (1957: 107) quote the Russian phonetician A. Thomson, who noted in 1905 that, not only do vowel onsets and offsets from and to different consonants sound different, but those contexts exert their effects upon the vowel centres as well: "... even in the central part of the vowel there is no complete constancy in pitch. The same movement from the characteristic pitch of the preceding consonant to that of the following consonant continues here too." See also Sweet (1929: 62) on the influence of /r/ on preceding vowels.

two seminal articles were published.[63] Stevens and House observed the spectral variation in American English vowels as a function of consonantal context; Lindblom conducted a similar study for the vowels of Swedish. These two papers inspired further research into coarticulation, which, in turn, revealed related issues requiring investigation. The number of such studies appears to have grown exponentially over the years, and there is indication that the trend will continue: an international consortium—ACCOR—has been established to assist and coordinate cross-language research into the phenomenon; its goals are expressed by Marchal and Hardcastle (1993: 138) as follows:

> The ACCOR project aims to provide a detailed description of the main articulatory and acoustic correlates of coarticulatory processes in seven European languages: French, English, German, Italian, Catalan, Swedish, and Irish Gaelic. A cross-language approach is adopted as a means of differentiating between the major language-independent universal regularities of these processes and language-specific factors such as the phonological rules of the language.

Much intensive study of coarticulation and related issues has been conducted over the past three decades; it is not surprising to note, therefore, that the body of literature on the topic is extensive, and treats a good number of aspects which cannot be covered in this review. Among these excluded

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63 Two earlier studies, Tiffany (1959), and Shearme and Holmes (1962), investigated acoustic variability in vowels, but did not isolate consonantal environments.

aspects are effects of vowels on contiguous consonants (e.g., Öhman, 1966; Gay, 1979; Mann and Repp, 1980), of vowels on trans-consonantal vowels (e.g., Öhman, 1966; Benguerel and McFadden, 1989), and of consonants on contiguous consonants (e.g., Gibbon et al., 1993). Similarly, questions of resistance of certain segments to coarticulatory influence,[64] and of direction and extent of influence are not treated herein.[65] Finally, the necessity of accounting theoretically for the phenomenon of coarticulation has fostered the formulation of several models of speech production and perception,[66] consideration of these must also remain beyond the scope of the present study.

As has been stated above, the present concern is to investigate, for English and French, the variation in vowel timbre—particularly that of the high vowels—which occurs as a function of the consonantal context in which the segments in question are found. The central focus is on the acoustic

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64 See, for example, Recasens (1985) and Recasens et al. (1993).

65 Questions of direction of influence involve investigation of the relative prominence of anticipatory or right-to-left coarticulation (where earlier segments are altered by the presence of a phone occurring later in the speech chain) and carryover or left-to-right coarticulation (where articulatory movements for an earlier segment affect later ones). Extent of influence studies are concerned with the number of segments across which coarticulatory effects are spread, as well as whether such effects traverse syllable and/or word boundaries. For a dated, but still very useful review of investigations into these and other facets of coarticulation, see Sharf and Ohde (1981).

66 See, for example, Fowler (1980); Bell-Berti and Harris (1981, 1982); Syrdal and Gopal (1986); and Nearey (1990, 1992). Van Son (1993a, 1993b) gives very helpful detailed reviews of some of these theories.

dimensions of that variation and on their perceptual correlates. Previous research dealing with these issues is discussed immediately below. A few findings which emerge from articulatory studies are considered farther on, in the section on "Theories and Findings for Coarticulation in French".

CONTEXTUAL EFFECTS IN ENGLISH

Effects of Consonants on Vowels: Acoustics

As has been noted above, the pioneering study for English of the acoustic dimensions of contextual effects of consonants on vowels was conducted by Stevens and House (1963). In this investigation, three adult male speakers of American English were recorded as they pronounced nonsense utterances of the form /həCVC/. The vowels involved were /i, ɪ, ɛ, æ, ɑ, ʌ, ʊ, u/; the pre- and post-vocalic consonants—non-nasal stops, fricatives and affricates—were always identical. In addition, the speakers produced the same vowels in isolation and in /h_d/ context for comparison with those in the /C_C/ environments. Vowel formant values used were the averages of values taken at three sampling points spanning approximately 25 ms in the temporal centre of each vowel.

While these authors did not provide actual formant values varying as a function of context, they did illustrate them graphically (Figure 6, p. 119). Through scaling of a magnified copy of this figure, the values for the vowels /i/ and /u/ have been derived and are shown in Table 1.[67]

TABLE 1: Values (in Hz) of the first two formants of /i/ and /u/ in four symmetrical /C_C/ contexts; values are derived from Figure 6, p. 119 of Stevens and House (1963).

	F1–/i/	F2–/i/	F1–/u/	F2–/u/
Null	290	2330	320	850
Labial	305	2250	325	965
Postdental	290	2250	295	1200
Velar	310	2260	325	1020

Among the findings to emerge from the data of this study were that there was no significant difference between values of F1 and F2 in isolation and in /h_d/ context (p. 116), and that, compared with pooled values from these "null" environments, shifts in F1 values in all consonantal contexts were small (p. 117).[68] By contrast, as is shown in Table 1, variation in F2 as a

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67 The formant values shown here for the null environment are not derived from the graph, but are reported as shown in Table 1 of Stevens et al. (1966: 126). It can be mentioned here that derived values for the null environment varied by no more than 5 Hz from the values reported in this latter article.

68 Commenting on findings similar to these with respect to coarticulatory effects on F1, Stevens et al. (1966: 126) note the following:

> The first formant contour is almost always characterized by a maximum at some point between the vowel boundaries and by relatively low values for the initial and final frequencies. This form of the first-formant curve is to be expected, since acoustical theory [the authors cite Stevens and House (1961) and Fant (1960)]

function of surrounding consonants is substantial, especially in the case of the vowel /u/ in postdental and velar environments.[69]

In an attempt to investigate the relative degrees of coarticulatory effects of prevocalic and postvocalic consonants on second-formant frequencies of vowels, Ohde and Sharf (1975) recorded five adult male speakers of American English as they spoke nonsense items having the form /CVhV/, /hVCV/, and /CVCV/, (as well as vowels in isolation, which were used to establish values for a null environment). The consonants used were /b, d, g/, and in CVCV items, the second consonant was identical to the first. The vowels were /i, u/; in all tokens, the second vowel was identical to the first; only the

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would predict a decrease in F1 when the vocal tract moves from a relatively unconstricted vowel configuration to a constricted or stopped consonantal configuration. Thus the first-formant contour for a given vowel would have the same general form for any consonantal environment, ...

69 As was mentioned in the introduction to this chapter, Lindblom (1963) concluded from his study of Swedish vowels that vowel duration was the primary determinant of undershoot. In a subsequent study to that of Stevens and House (1963), Stevens et al. (1966) analyzed similar speech tokens (or re-analyzed the same tokens) using analysis-by-synthesis techniques. One of the findings from this latter investigation was that, while there was some correlation between rapidity of speech and degree of undershoot, "the tendency is by no means consistent across all vowels and all consonantal environments" (p. 131). Dealing with a parallel issue, Delattre (1969) noted six factors which may affect vowel variability differently from one language to another: rhythm type, muscular tenseness/laxness, stress, duration, intensity (loudness), and contextual assimilation. More recently, Van Son (1993a) correlated degree of undershoot in Dutch vowels with some of these factors. His findings led him to conclude (p. 123) that "whatever the cause of formant-undershoot ..., it is not the mechanical limitations of the human articulators [i.e., limitations which prevent them from reaching their targets in short periods of time]"; and, echoing Whalen's (1990) conclusion from his study of English, that "it is more likely that undershoot is to a large extent planned".

first vowel in the string was analyzed. In addition, one of the speakers read /hVC/ tokens to provide an opportunity for comparison of effects of postvocalic consonants which are followed by a another vowel on the one hand, and which are utterance-final on the other. Spectral values were taken from narrow-band spectrograms "at the most stationary portion of F2". Exceptionally, in the case of tokens of /duhu/, where it was often difficult to find a stationary portion of the formant, "frequency of F2 was measured at the termination of the vowel" (p. 924).

Once again, presentation of the data from this study requires some reconstruction. Means of raw F2 values are not provided; instead, for each vowel in each environment, the authors present (p. 925) a mean undershoot value,[70] as well an undershoot percentage score. From these two sets of numbers, the raw F2 means can be computed; these values are shown in Table 2, below.[71] Comparison of differences between values within the various contexts and those in the null environment shows (1) that the coarticulatory effects of a preceding consonant are substantially greater than

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70 This undershoot value is the absolute value of the difference between the F2 value for the context in question and that for the null environment (see Ohde and Sharf, 1975: 924).

71 Ohde and Sharf (1975: 924) reported that their F2 values were made to the nearest 25 Hz. With undershoot values and percentages given for 3 consonants (/b, d, g/) and 2 context types (VC and CV), 6 different values for the null environment can be calculated for each vowel. The null-context values displayed in Table 2 herein were also taken to the nearest 25 Hz and were chosen in such a way that actual digressions from this value can be accounted for by rounding.

those of a following consonant; and (2) that, while F2 undershoot is generally greater in vowels preceded and followed by identical consonants than in those followed by a neutral /h/, such is not always the case (notably, in tokens of /didi/ and /bubu/).[72]

TABLE 2: Values (in Hz) of the second formant of /i/ and /u/ in null environment and in three types of consonantal environments for three consonants; values are derived from Tables I and II, p. 131, of Ohde and Sharf (1975).

	/iC/	/Ci/	/CiC/	/uC/	/Cu/	/CuC/
/b/	2320	2242	2220	1053	1100	1093
/d/	2335	2238	2255	1062	1417	1516
/g/	2357	2279	2272	1070	1185	1215
Null		/i/: 2375			/u/: 1000	

Table 3 presents F2 undershoot values for the English vowels /i, u/ between identical consonants from the two studies considered in this review. The undershoot values from Ohde and Sharf (1975) are substantially greater than those from Stevens and House (1963), with a single exception (/u/ in the labial environment). Nonetheless, the broad trends are quite similar: (1) F2 undershoot is greater for /u/ than for /i/; (2) minimal coarticulatory effects occur in a velar environment for the /i/ and in the labial environment for /u/; (3) the formant shift for /u/ in postdental environment is very large.

72 Coarticulatory effects were generally smaller for the vowel of /hVC/ tokens than for the first vowel of /hVCV/ tokens (Ohde and Sharf, 1975: 925-926). It must be recalled, however, that this finding is based on the analysis of the speech of a single subject.

TABLE 3: Values (in Hz) of F2 undershoot of /i/ and /u/ in three symmetrical /C_C/ contexts from Stevens and House, 1963 (SH) and from Ohde and Sharf, 1975 (OS); numbers shown were obtained by subtracting F2 values for each context from those of the null environment.

	/i/-SH	/i/-OS	/u/-SH	/u/-OS
Labial	80	155	-115	-93
Postdental	80	120	-350	-516
Velar	70	103	-170	-215

Effects of Consonants on Vowels: Perception

The findings of Stevens and House (1963) with respect to the acoustic dimensions of coarticulation prompted these authors, not surprisingly, to speculate about the perceptual correlates of the phenomenon:

> Data of the type presented here provide further evidence of the important role played by contextual effects in the process of speech perception. The identification of a vowel generated by a particular talker in a given consonantal context must be made ... relative to the changes that occur in the acoustic signal between the vowel and its adjacent consonants. The rules that must be invoked in order to take account of these contextual effects seem to be describable in a relatively simple fashion in terms of the static and dynamic properties of the human vocal mechanism. Such rules must somehow be learned by listeners during the acquisition of language through constant exposure to their own speech and to the speech of others. (p. 127)

In the years following their study, some of the speculations of these authors have found empirical corroboration in a considerable number of perceptual investigations.

One such study is that of Lindblom and Studdert-Kennedy (1967). In the first of their experiments these researchers constructed a 20-step /ʊ/-/ɪ/ continuum of synthetic vowels varying in F2 (about 53 Hz/step) and in F3 (28 Hz/step); F1values were held constant at 350 Hz. These vowels were affixed to pre- and post-vocalic transitions appropriate for /w/ and /j/ to form symmetrical CVC nonsense items, which, along with the vowel signals in isolation, were played to 10 native speakers of American English for a forced-choice identification task. The results showed that the /ɪ-ʊ/ boundary for the /wVw/ environment was located at an F2 value which was about 320 Hz lower than that for isolated vowels, and that the boundary for the /jVj/ environment was approximately 80 Hz higher (p. 835). The authors concluded (p. 837) that "[f]rom the point of view of certain acoustic attributes of vowels, it would appear that the processes of vowel production and vowel recognition have complementary rôles: recognition compensates for production." Elsewhere (p. 841), they add that "articulatory activity is characterized by undershoot and perception by overshoot."

In a similar study, Ohala and Feder (1987)[73] constructed a 17-token synthetic /u/-to-/i/ continuum varying in 75-Hz steps in F2 (from 950 to 2150 Hz) and in 50-Hz steps in F3 (from 2150 to 2950 Hz); F1 was held constant.[74] For one of the experiments in this article, these tokens were embedded in nonsense words of the form /Vbə/ and /Vdə/ and were played to native speakers of American English for a forced-choice vowel identification task. Results showed that the /u/-to-/i/ crossover (the point at which listeners identify half of the tokens as /u/ and half as /i/) shifted towards "fronted" values in the /Vdə/ environment, as compared to the /Vbə/ environment—that is, while before /b/, this occurred approximately where F2 = 1625 Hz and F3 = 2600 Hz, before /d/, it was found at F2 = 1700 Hz and F3 = 2650 Hz.[75] The researchers took this shift as an indication that "listeners allowed for and factored out the elevated F2 that alveolar consonants produce on back vowels" (p. 121).

The results from the above-mentioned studies reveal a striking difference: i.e., the labial-to-postdental boundary shift reported in the latter is quite small in comparison to those found in the former. The explanation for this may lie in the relatively small coarticulatory effect of a consonant on a

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73 For a more recent report on this study, see Ohala and Feder (1994).

74 Spectral values reported here are derived from Figure 1 of Ohala and Feder (1987: 120).

75 See Figure 4 of Ohala and Feder (1987: 121).

preceding vowel as compared to that of a consonant on a following vowel (Ohde and Sharf, 1975), in differential effects of semi-vowels and obstruents, and/or in the fact that the one study deals with the so-called "tense" vowels /i, u/, and the other with "lax" /ɪ, ʊ/. Still, both studies show that listeners expect coarticulatory effects and allow for them in their vowel categorizations. Moreover, such findings are not isolated. Similar results have been reported for perception of English vowels in other CVC contexts (e.g., Ohala et al., 1978; Ohala, 1981) and in CV contexts (e.g., Whalen, 1989).[76] Taken together then, the studies noted so far in this chapter provide ample evidence that contextually-determined variability is a fact of English vowel production and perception. As will be seen below, all appearances suggest that no comparable studies have been conducted for French.

CONTEXTUAL EFFECTS IN THE PEDAGOGY OF L2 PRONUNCIATION

If investigation into coarticulatory effects has not yet been conducted for French, there should be no surprise in noting that, generally speaking, little importance is placed on such effects in the pedagogy of French pronunciation. Most of the manuals consulted for this review contain no

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76 It might be noted here that studies have also shown vocalic environment to affect the identification of consonants (e.g., Mann and Repp, 1980; Whalen, 1989), and consonantal environment to affect the categorization of other consonants (e.g., Mann and Repp, 1981).

mention of the phenomenon. One exception to this is Rochet's (1990: 50) recommendation of a strategy for mastering the difficulty of pronouncing an adequately backed French /u/ following a dental consonant. A further, more sweeping, departure from this general pattern is in Valdman's (1993) programme, which incorporates the notion of "optimal contexts" for the production of vocalic segments. With regard to the pronunciation of French /i/, for example, this author states the following:

> Comme /i/ est une voyelle aiguë, son contexte optimal est constitué par les consonnes les plus aiguës, les dentales /t, d, s, z/. Par contre, il sera plus difficile d'obtenir une tension maximale avec les consonnes graves /p, b, m/. Les autres consonnes sont plus ou moins neutres. ... La série suivante illustre la progression sur l'axe de l'acuité. Vous noterez que dans le premier mot, il vous sera plus facile de produire le phonème avec une forte tension, et qu'il vous faudra faire un effort de plus en plus croissant au fur et à mesure que vous progresserez dans la série: *site, type, dis, gîte, chic, fils, vite, lis, niche, qui, gui, riche, pire, abîme, mime.* (p. 45)

In a similar vein, concerning French /u/, Valdman notes the following:

> Du point de vue acoustique, les contextes optimaux pour la prononciation de /u/ sont les consonnes graves /p, b, m/ et une intonation descendante. Notez la plus grande difficulté à produire un /u/ très grave au fur et à mesure que vous procédez dans la liste suivante: *mou, la boue, le pou, le cou, le fou, le loup, la joue, le chou, doux, tout, sous.* (p. 47)

Such progression from lesser to greater difficulty, then, is followed in pronunciation exercises which lend themselves to such ordering.

Thus, this programme applies principles of contextual effects to assist in the mastery of difficulties of production rather than of perception. In his preface, the author lists this application of the notion of optimal contexts as one of the innovations of the programme: "A l'analyse articulatoire des voyelles s'ajoute l'analyse acoustique pour identifier des contextes qui favorisent la production d'un son particulier." (p. x) Still, in spite of the claim, no supporting acoustic analyses are either presented or cited. It would appear, then, that Valdman's estimations of relative difficulty, and Rochet's note concerning /u/ next to dentals (cited above) have been based on practitioners' experience rather than on documented findings. Both rest on the judgement that French /u/ varies less as a function of consonantal environment than does English /u/. Similarly, Valdman's note concerning the optimal environment for /i/ assumes that the same holds true for that French vowel as well.

While contextual effects are generally accorded little importance in the pedagogy of French pronunciation on this continent, they play a central role in an approach (not yet mentioned in this review) which has been practiced in Europe for several decades. The Verbo-Tonal Method is the approach to phonetic correction practiced within the broader tradition of the Structuro-Global Audio-Visual Method (SGAV) of second-language instruction

(Landercy, 1976). Landercy and Renard (1976: 175) give as a fundamental tenet of the Verbo-Tonal approach the principle that accurate pronunciation is to be fostered through the development of accurate perception.[77] Central to this procedure is the presentation of sounds to be mastered, once again, in their optimal contexts, which, for vowels, are those in which formant transitions from and to consonants show minimal movement. Such an environment is to be preferred, apparently, because it demands the smallest degree of *perceptual* effort (p. 187). The broad principle to be followed, then, is to present vowels in the context of consonants which "resemble" them in terms of their placement on a light-to-dark axis:

> Le stimulus optimal sera celui qui nécessitera un minimum d'effort audio-phonatoire, c'est-à-dire ce qui associe clair avec clair et sombre avec sombre et engendre ainsi des transitions formantiques aussi peu marquées que possible. (p. 188)

Thus, for example, the ideal context for accurate perception of French /u/ is adjacent to labial consonants or [ʀ], while the best environment for /i/ is next to dentals (pp. 177-178).[78]

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[77] A complete review of the Verbo-Tonal method must remain beyond the scope of this present study. For a brief overview of the approach, the reader is directed to Landercy (1976); a much more detailed description can be found in Renard (1979).

[78] While great importance is placed on the principle of maintaining flat transitions, it appears that, at least in some cases, the optimal environment is to be chosen with an eye to the actual pronunciation mistakes of the learners in question, as is noted by Landercy (1976: 164): "Une fois la faute localisée, on peut donc savoir si le son est perçu trop clair ou trop sombre et l'associer en conséquence. Le problème réside uniquement dans la détermination du sens de la faute." Thus, for example, for the learner who pronounces a

The principles of this aspect of the Verbo-Tonal approach rest on the acoustic and perceptual dimensions of contextually-determined variability, and while it is not difficult to find claims concerning the empirical foundation of the approach and its grounding in acoustic phonetics (Landercy, 1976: 164; Landercy and Renard, 1976: 178), the evidence cited in support of the principles comes from articulatory studies.[79] Almost a decade after the appearance of these two writings, when Harmegnies (1985: 57) published the results of an investigation into the acoustic variability of /s/ and /ʃ/ as a function of vocalic environment, the situation had not changed; this study was claimed by its author to constitute a first step in satisfying the need within the Verbo-Tonal school for acoustical research which might serve to specify "la nature acoustique des règles de la phonétique combinatoire habituellement basées sur un raisonnement articulatoire".[80] Thus, it appears

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French /y/ which tends towards /i/ the optimal context would presumably be labial, while for the one whose realization of the vowel tends towards /u/, it would be dental.

79 Landercy and Renard (1976: 177) and Renard (1979: 85) cite two works as evidence in support of their claims concerning contextual effects. These two cited works offer detailed findings of cineradiographic investigations of the articulation of French consonants (Simon, 1967) and of French vowels (Brichler-Labaeye, 1970). While the latter did find clear evidence of coarticulatory effects of consonants on vowels (e.g., a more fronted /ɔ/ in *poste* than in *pope*—see p. 103), it is important to remember that there is no one-to-one relationship between articulatory gestures and acoustic results (e.g., Ohala, 1974). Furthermore, in the absence of acoustic evidence, one can have no idea of *how much* the vowel in question is affected by surrounding consonants.

80 Harmegnies (1985: 52) claimed to have chosen to investigate coarticulatory effects on consonants in order to provide a complement for a study on French /u/ (Renard, 1985) which was published in the same volume of the *Revue de Phonétique Appliquée*. While the

that, as recently as 1985, no results from investigations into the acoustic or perceptual dimensions of coarticulatory effects on French vowels had been published.[81] And no subsequent study has come to the attention of this writer.

THE OBJECTIVES OF THE PRESENT STUDY

What is presented herein is a cross-language study of the coarticulatory effects of consonants on the high vowels of English and French. The focus of attention is centred on the acoustic manifestations of those effects, and on their perceptual correlates. While, as is noted above, such investigations have already been conducted for English, all appearances would suggest that no similar work has been done for French. What is described here then, is a study which attempts to replicate for English the acoustic and perceptual findings of researchers such as those noted above. Secondly, it extends the investigation to include those patterns of coarticulation in native speakers of

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former work did provide valuable insights into variability in consonants, the latter did not do so for vowels. Renard's study of contextual variation in /u/ is limited to the presentation of a single spectrum of the vowel in each of three different environments.

81 Chollet (1976, 1977, 1980) has found evidence that consonants do indeed affect the acoustic shape of vowels in French; however, these studies present no data on specific vowels.

Standard French. Finally, it observes the perceptual behaviour of French listeners as they hear the natural speech samples of speaker of English.

This study should serve several purposes. First, it is judged here that the absence of investigations into the acoustic and perceptual dimensions of coarticulation in French constitutes a serious gap in our understanding of the phonology of that language. As is noted early in this chapter, the ACCOR consortium has set for itself the mandate to compare coarticulation in seven European languages, but it has chosen to limit its attention to the production side of the phenomenon (Marchal and Hardcastle, 1993). Useful as this project is sure to be, it will not provide all the answers which are needed.[82] By way of illustration of this point, one might consider Nearey's (1990, 1992) Double-Weak Theory of Speech Perception. This author has proposed a model of perception which takes into account what has been discovered so far from research into all three facets of speech communication: articulation, acoustic product, and perception. There is great interest in the field of general phonology in determining to what extent this and other such models can account for speech perception in other languages. In order for that to be accomplished, of course, there is a need for data: articulatory, acoustic, *and*

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82 This judgement is not to be construed as a criticism of ACCOR. Even with the limits the consortium has adopted, the project is extremely ambitious. The point to be taken here is simply that work remains to be done beyond the ACCOR mandate.

perceptual data. At present, for French, there are gaps in that database. This study is expected to take a first step in filling some of those gaps.

Secondly, as Harmegnies (1985) has noted (see above), the Verbo-Tonal approach requires some language-specific empirical support for its theoretical foundation; that is, where the task of phonetic correction in French is concerned, it needs to be shown that French vowels do indeed manifest significant acoustic variability as a function of their consonantal environment. As well, Valdman's (1993) application of the optimal production environment is based on the assumption that coarticulatory effects of consonants on vowels are greater in English than in French. While experimental findings for English might lead one to suspect that such is indeed the case, the accuracy of that assumption remains to be demonstrated.

Thirdly, for the majority of programmes, those which do not broach the issue of contextual variability—indeed for all programmes of French pronunciation—it is important to know how the native speaker of French pronounces and perceives vowels in their various environments. That is, it is of fundamental importance that practitioners have a very clear idea of the real phonetic shape of the targets they are trying to help their students attain. In leaving untreated the question of contextual variation in French vowels—as is the current norm—there is a tacit assumption, for example, that French /u/ is

[u], regardless of where it happens to fall. To date, that assumption has been neither confirmed nor refuted. Clearly, this is an issue which begs to be addressed.

Finally, associated with this study there is an opportunity to contribute to our understanding of the nature of phonetic difficulty in second-language learning. As is noted in the preceding chapter, it is the opinion of this writer that Kohler's (1981) principles of giving careful attention to phonetic detail and of observing separately the various facets of phonological behaviour (i.e., making conclusions concerning perception on the basis of perceptual data) represent the surest procedures for taking positive steps in that direction. By following those principles, Rochet (1995) has brought us one step closer to an understanding of the nature of the difficulty associated with the French high vowels in particular, and, therefore, with L2 vowels in general. The intention here is to extend the work begun by this researcher, and to take yet another step toward a more solid conceptualization of second-language phonetic difficulty.

This final purpose for the present study is deemed to be among the most important, for there is potential for immediate practical application of the kind of understanding which is sought. As an illustration, consider the following assertion in Dansereau (1990: 78): "La prononciation de la voyelle

[y] en français pose souvent beaucoup de problèmes pour l'étudiant anglophone, car il n'existe pas de voyelle équivalent en anglais standard." No such claim concerning difficulty is made with regard to French /u/.[83] Rochet's (1995) findings raise serious questions about such difference in treatment of these two vowels. Moreover, the greater difficulty attributed to French /y/ than to /u/ fails to find confirmation in the day-to-day observations of the teacher, who notes that, while students' pronunciations of *bu* frequently sound like *bout*, it is also true that, when they say *tout*, it sounds like *tu*. Thus, to this language teacher at least, a more intuitively appealing claim would have it that the French vowels /y/ and /u/ both present high degrees of difficulty to English-speaking learners, each manifesting that difficulty in different consonantal environments. It is hoped that the present study will be able to suggest a more solid characterization of the task which learners face.

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[83] For a similar assessment of how these two French vowels relate to the English system, see Carduner and Hagiwara (1984: 101-102).

DESCRIPTION OF THE STUDY

Acoustic Analysis

The experimental design called for native speakers of Standard French and of Canadian English to record monosyllabic "words" for acoustic analysis. In another phase of the study, some of these speech tokens produced by English speakers were to be played to French listeners for a vowel identification task. It was decided to limit consideration to the high vowels of the two languages (/i, u/ for English, and /i, y, u/ for French) in CVC syllables which are symmetrical from the perspective of the point of articulation of the two consonants. This syllable structure was chosen in order that, generally speaking, the greatest degree of variability in vowels might be found (cf. Ohde and Sharf, 1975).

The limitation placed on the vowels was motivated by several considerations. First, the high-mid vowels /e, (ø,) o/ were excluded because of their limited occurrence in checked syllable in French.[84] Secondly, the low-mid vowels /ɛ, (œ,) ɔ/ were dropped because of the merger of /ɑ/ and /ɔ/ in some varieties of Canadian English (Avis, 1975). Thirdly, while it had been

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84 Some of these vowels do occur in closed syllable for some speakers of European French; however, in southern French, the dialect of most of our subjects, all are proscribed in this environment. See Rochet (1982), and Valdman (1972).

intended to include low vowels, this plan was abandoned early, because of complications associated with the non-universality of this merger.[85]

Since the signals to be used for acoustic analysis of English were also to be used as the items of a vowel identification test for French listeners, it was important to control for the perceptual bias in favour of real lexical items over nonsense words (Centmayer, 1975). By choosing as consonants for English speech items the voiced obstruents /b, d, g/, one arrives at the following possible perceptual items for French: /bib/, /byb/, /bub/, /did/, /dyd/, /dud/, /gig/, /gyg/, /gug/. None of these exists as a lexical item in French. Since no parallel test of vowel identification was to be administered to English listeners (see below), the lexical status of the French speech items was not a concern and the same environments (/bVb/, /dVd/ and /gVg/) were retained.

These CVCs were embedded in a carrier sentence which would place them in stressed final position. In order to guard as much as possible against

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[85] This occurred during the recording of the English speech samples. While the English-speaking subjects consistently gave /ɑ/ for the vowels in *bob* and *dod*, just over half pronounced *gog* with /ɔ/. For those speakers who maintain a distinction between /ɑ/ and /ɔ/, minimal pairs are not difficult to find: e.g., *tot~taught, cock~caulk, popper~pauper.* However, for the author, and apparently for a good number of the subjects, the /ɑg/ sequence is rather rare, appearing almost exceptionally in the word *lager*. It is worthy of note, perhaps, that the exclusion of the low vowels from the study is unlikely to have caused the loss of interesting results; the primary phonetic characteristic of the French low vowels, /a/ and /ɑ/, is high and unpredictable variability (Mettas, 1970).

coarticulatory effects from a transconsonantal vowel (Öhman, 1966; Benguerel and McFadden, 1989), the tokens were preceded by the definite determiners *the* and *le*, so that that vowel might be as acoustically neutral as possible in both languages. Finally, to prevent the deletion of that [ə] in French, a word ending in a consonant was chosen to precede the determiner; this yielded a sequence of consonant + liquid + /ə/, a string from which the unstable *e* cannot be deleted (Rochet, 1990: 245-252). The carrier sentences chosen after these considerations were *I said the* ... for English, and *Je répète le* ... for French.

For the recording of English speech samples, then, the items *beeb, boob, bob, deed, dude, dod, geeg, goog, gog* represented orthographically as shown here, were embedded in the carrier sentence. Ten groups of these sentences were produced, such that each group contained a token of /u/ in each environment and three of the six tokens with /i/ and /ɑ/. Items within groups were placed in random order with the constraint that identical tokens were not permitted to lie adjacent to one another across group boundaries. This yielded a corpus for each subject of 60 items: 10 tokens of each word containing /u/, and 5 each of those containing /i/ and /ɑ/.[86] As has been

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86 In light of previous results concerning contextual effects on English /i/ and /u/ (Stevens and House, 1963; Ohde and Sharf, 1975), and concerning F2 vowel crossovers in English and French (Rochet, 1995), it was anticipated that the most interesting findings of this

noted above, the items containing /ɑ/ were later excluded from consideration. Three additional sentences, which were discarded, preceded and followed those containing tokens to be used. Similar procedures were followed for the development of the corpus for the natural speech signals in French, except that, in the end, each speaker would provide 10 tokens each of *bibe, bube, boube, dide, dude, doude, guigue, gugue, gougue.*

The subjects who provided the English samples are 12 native speakers of Canadian English, 7 men and 5 women, ranging in age from 36 to 55 years of age (mean = 45.9 years).[87] One of these reported having enough familiarity with French, Malagasy and Hausa "to get by", and another had just finished auditing a course in intermediate French; the rest are monolinguals. All said that they had no normal hearing deficiencies, and all are judged by the author to have speech representative of standard Canadian English. The subjects are faculty and staff employees of Concordia College, Edmonton, Alberta, who graciously consented to participate in the experiment, and who were excused from their normal work duties to do so. Subjects in the other group are 5 native speakers of European French, 2 men and 3 women, ranging in age from 26 to 57 years of age (mean = 38 years). All are members or associates

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study would involve the rounded vowels. This accounts for the imbalance in the total number of items for /i/ and /u/.

87 More detailed information concerning all subjects is presented in Appendix A.

of members of the Division of Romance Languages at the University of Alberta who, once again, agreed to provide speech material for analysis.

The English speech samples were recorded using a SONY TC-D5 Pro II cassette recorder and a Sennheiser MD 421N microphone in a small, quiet room at Concordia College. Recording of the French samples was carried out in a recording studio at the University of Alberta. For three subjects, the same equipment was used, however, this was not available at the time of the recording of the remaining two subjects; for these a SONY TCM-5000EV cassette recorder and a Shure PE85L microphone were used.

The English samples were low-pass filtered at a corner frequency of 8.8 kHz and digitized at a sampling rate of 22 kHz. (The filter used here was not available when the French recordings were to be processed, so a different filter, with a corner frequency of 4.8 kHz was used.) The carrier sentences were then digitally excised. Values of F2 for each token were taken at the F2 peak (i.e., at the point in the signal where F2 was at its minimum or maximum, depending on the direction of its movement), but with the further constraint that, if the peak occurred at a point beyond the temporal half-way point in the vowel, the value was taken at the half-way point. This procedure was an attempt to ensure that values recorded would represent vowels rather than glides.

Natural-Speech Perceptual Test

As is noted above, speech samples gathered for acoustic analysis of English vowels were also to be used as the linguistic material in a perceptual test for French listeners.[88] This test contained 2 tokens each of /bib/, /did/ and /gig/, and 7 each of /bub/, /dud/ and /gug/ from each of ten of the English speakers; it thus comprised a total of 270 English items. The speech samples of two male speakers were eliminated due to the virtually complete absence of final consonant release in the /bVb/ tokens. Within the samples from each of the remaining speakers, seven of the ten tokens for each item were chosen for the test. The procedure followed here involved, first, the elimination of signals judged by the author to be the least acceptable to listeners in general (i.e., items with low amplitude, transients from paper movement, and the like) and to French listeners in particular (especially absent or weak release of the final consonant). In the cases where more than seven tokens per item remained after such culling, subsequent eliminations were done with an eye to maintaining the F2 variability within the original set

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[88] The original intention to present a parallel test (containing natural French speech samples) to English-speaking listeners was abandoned. This had been adopted largely in the interest of symmetry of experimental design. However, it appeared doubtful that such a test would yield revelations which would not be available from the results of the synthetic-signals test. In addition, the central interest here is in the phonetic difficulty of English speakers learning French, rather than the converse—that is, on the particular difficulty of learners whose L1 has a single phoneme which corresponds to two in L2. (See Rochet, 1994; 1995).

(an initial acoustic analysis had already been completed). That is, if a single token was to be eliminated, the one nearest the mean was chosen; if two were to be excluded, the choice fell on signals having F2 values on either side of, and approximately equidistant from the mean.

The listeners were 14 native speakers of French, 9 males and 5 females, ranging in age from 12 to 75 (mean = 35.9 years). Of these, 12 are from the department of la Gironde in southwestern France.[89] One of these speaks fluent Spanish; the rest are monolinguals. The two remaining subjects (one from southern France, one from the north) are fluent speakers of English. All reported normal hearing. The perceptual test was administered to these listeners via a hypertext programme on a personal computer; signals were delivered binaurally through AKG K141 earphones. The English speech samples were presented in random order for a forced-choice identification of the vowel. Each item was repeated twice initially, and subjects could request (through a mouse click) as many extra repetitions of an item as they wished before registering their response. They made their identification responses by clicking inside one of three boxes labelled "i", "u", and "ou", according to the

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89 The completion of the preparation of this perceptual test coincided with a windfall of good fortune. Professor B. Rochet, supervisor of this study, offered to take the test with him on a trip to France and to find subjects to participate. His invaluable assistance in this regard is greatly appreciated.

standard French orthography for the vowels /i/, /y/, and /u/. If they inadvertently registered an unintended response, there was an easy procedure for correcting it. The test took between fifteen and twenty minutes to complete.

Synthetic-Speech Perceptual Test

The speech materials[90] for this test were synthesized in cascade at a 10 kHz sampling rate using Klatt's (1980) cascade/parallel speech synthesizer to have frequency values appropriate for a male voice, with F0 of 120 Hz at the beginning of the vowel, and decreasing linearly to 100 Hz at the end. Duration of the vocalic portion of each signal was 165 ms. The vowels in the continuum had a constant F1 value of 250 Hz. F2 varied between 500 and 2400 Hz in 100-Hz steps.[91] F3 was fixed at 2300 Hz for stimuli with F2 values up to 1800 Hz; for signals having F2 greater than 1800 Hz, F3 increased by 140 Hz per step to a maximum value of 3140 Hz.[92] The spectral values of the signals in this continuum are plotted in Figure 1.

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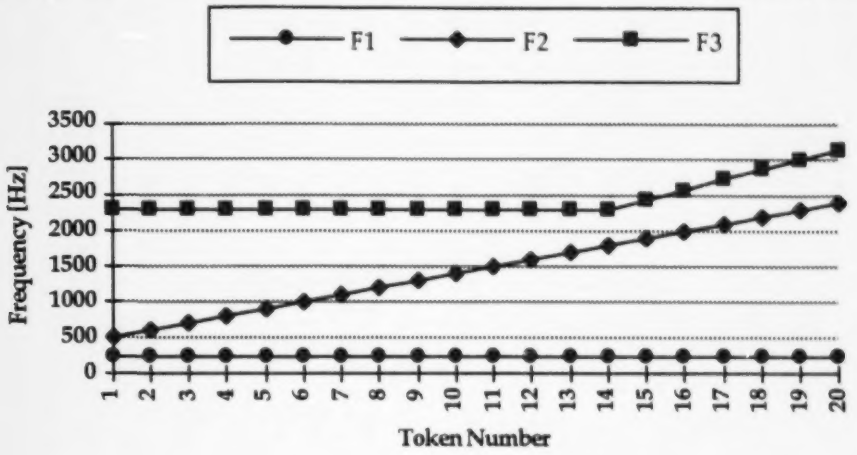
[90] The assistance provided by B. Rochet and T. Nearey in making available this synthetic continuum is gratefully acknowledged.

[91] By error the spectral shape of the /bV/ continuum was not identical. This alteration is described in more detail in the chapter on *Results and Discussion*, below.

[92] See Nearey (1989) on the topic of the relationship between F2 and F3 in high vowels. In order to check the validity of this continuum, the formant values found here in the acoustic analysis of English and French vowels were averaged across all male speakers and across all environments, and were compared to the best match for each vowel in the

Figure 1: Spectral values of members of the synthetic continuum used for the perceptual test.



Two sets of the vowels in this continuum were affixed to prevocalic transitions appropriate for /bV/ and /dV/ syllables;[93] a third was left to give vowels in isolation. This procedure yielded three tests, each containing 20 stimuli, which were presented 10 times in random order for a forced-choice identification. The signals were low-pass filtered at 4.8 kHz and delivered binaurally through TD-149 headphones.

The nine French listeners who participated in this test are all monolinguals from the department of la Gironde; eight of them also took part

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synthetic continuum. These data are given in Table 18 of Appendix B. As is shown in that table, the synthetic continuum contained a very close approximation to each French and English vowel as defined by those mean formant values. It might be mentioned as well that one of the French subjects, Fr02, judged three contiguous members of the continuum (nos. 3, 4 and 5) as good exemplars of /u/ (9 on a scale of 9) and three as good exemplars of /y/ (nos. 13, 14 and 15).

93 The values used in these transitions are given in Table 17 of Appendix B. With minor adjustments, they reflect the findings of Nearey and Shammass (1987) and those of Allen, Hunnicut and Klatt (1987).

in the identification of the natural English signals. There were six males and three females. Ages ranged from 21 to 75, with a mean of 39.8 years. The twenty-one English listeners, 11 males and 10 females, once again, are co-workers at Concordia College; all are monolingual speakers of Canadian English. Ages ranged from 23 to 54, with a mean of 40.5 years. The French subjects identified the vowel in each token as /i/, /y/, or /u/, the English subjects as /i/ or /u/, using procedures similar to those described above for the natural-signals test.

THEORIES AND FINDINGS FOR COARTICULATION IN FRENCH

While it appears that no investigation has been done into the acoustic and perceptual facets of contextual effects on French vowels, there are two theories which can perhaps suggest the kinds of results which might be expected in this study. In addition, there are a few studies which have dealt with some fine details of the articulatory dimensions of coarticulation, and whose results may provide some clues. These are considered in this section.

Delattre's Modes

One theoretical tradition from which may be gleaned some predictions concerning English-French differences with regard to coarticulatory effects is Delattre's (1951) modes of articulation, introduced above (pp. 14-16). As was noted in that discussion, one of the three modes held to characterize French articulation, the *mode croissant*, signifies fundamentally the French preference for open syllabification. This implies the existence of a tight bond between a vowel and the consonant(s) which precede(s) it, and a clear separation between that vowel and the consonant(s) which follow(s) it (Delattre, 1966: 12). From this, on the surface at least, one might expect high levels of coarticulatory influence running in both directions within a CV sequence, and much less influence in either direction within a VC sequence. However, a second facet of the *mode croissant* is a postulated tendency to maintain levels of articulatory energy expenditure throughout the course of the production of a vowel. This entails an "anticipation" and, therefore, a "psychological preeminence" of the vowel in French speech (p. 12). Two products of this tendency are postulated: a "centrifugal" articulation pattern,[94] in which all

[94] Matte's (1982) claim is that a language of centrifugal articulation is characterized by extremes of articulatory movements and positions: e.g., back articulations are very backed, front articulations are very fronted; rounded lips are very rounded and projected, and unrounded lips are tightly stretched. In contrast to French, English is a language of "centripetal" articulation, and is characterized by non-extreme movements and positions.

features of a vowel are maximally distinguished from those of a central or "neutral" vowel and from those of the other vowels of the system (Matte, 1982: 133), and a resistance within vowels to influences from consonants in general, regardless of where the latter occur (p. 61).[95] Thus, from the point of view of the modes, one would predict that French vowels—i.e., *all* French vowels—will show significantly less influence coming from surrounding consonants than do English vowels.[96]

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95 The articulatory explanation advanced for this resistance is the hypothesized separation of roles among articulators: "La mâchoire inférieure s'occupe surtout de l'aperture des voyelles, tandis que l'articulation des consonnes est surtout fonction de l'action des lèvres et de la langue." (Matte, 1982: 63) In a language governed by the opposing *mode décroissant*, such as English, the lower jaw plays an important role in the articulation of consonants. In such cases, the tongue and lips "lose their agility" (pp. 60-61). It is not clear how this separation of roles might lead vowels to resist coarticulatory effects along the F2 dimension.

96 The literature on the modes contains at least one serious and surprising inconsistency in this regard. In a reaction to some of Lindblom's (1963) conclusions, Delattre (1969: 300) asserted the following with regard to the effect of consonants on contiguous vowels:

> ... we can deduce that the formant [transitions] that precede and follow a vowel have a reducing effect, but a very different and much smaller one than the effect of stress. The formant-transition effect is acoustically translated by a relatively small attraction of formant-2 toward the loci of the contiguous consonants; it can add to, as well as subtract from, the centering effect of unstress depending on whether the consonant loci are higher or lower than the second-formant frequency of the vowel. *Not only is this effect small, but it is practically the same in all languages* [emphasis added] and, therefore, is of little interest for a cross-linguistic comparison such as the present one.

It is perhaps the case that Delattre's and Matte's pronouncements (noted in the text above) were made with an eye to resistance of French vowels to other kinds of coarticulatory influences, such as vowel nasalization in a word such as *nonne*, rather than F2 assimilation. Still, the pronouncements are stated as generalizations, and are stated often.

There is an interesting side issue surrounding Delattre's response to Lindblom's study. The reader gets the impression that the two writers were not really talking about the

The Density Hypothesis

One of the mandates adopted by the ACCOR consortium in its proposed investigation of coarticulatory patterns in European languages is to endeavour to substantiate a *density hypothesis*, according to which degree of contextual influence of one sound upon another varies inversely with the number of members of a phonological class (Marchal and Hardcastle, 1993: 139). A similar notion is labelled the "Theory of Adaptive Dispersion" or TAD (Lindblom and Engstrand, 1989). Flege (1989b: 124) explains this latter hypothesis in terms of talkers maintaining only "sufficient" phonetic contrast between vowels to accommodate the needs of listeners in order to "minimize articulatory effort". Manuel (1990: 1287) carries the explanation further:

> In some languages, very similar articulatory gestures may result in linguistically distinct phones. In order to maintain distinctiveness between those gestures, each must have a fairly narrow constraint on its production. On the other hand, if a language makes only a single phone in a particular region of some phonetic dimension, we might expect a fair amount of variability in production to be tolerated.

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same thing: the latter author's focus of attention was on coarticulation, while that of the former was on reduction or centralization of unstressed vowels. One is led to believe that Delattre's response would not have been written if Lindblom had chosen a term other than "reduction" for the phenomenon he studied. However, it is the opinion of some writers, at least, that they were indeed talking about the same thing. Van Bergem (1995) recently reviewed literature on, and conducted a study of, vowel reduction in Dutch; he concluded (p. 42): "In our view, the schwa is not a vowel with a target in the centre of the vowel triangle, but rather a vowel-like segment *without* target that is completely assimilated with its phonemic context." Otherwise stated, reduction is not a phenomenon separate from coarticulation; rather, reduction is the *end-point* of coarticulation.

This hypothesis would predict, then, that vowels in a densely occupied acoustic space will show less variability as a function of context than vowels in a sparsely occupied space. Flege (1989b: 124) notes a second prediction to emerge from this theory: namely, that "point vowels" (those which are articulated with the most extreme tongue positions—i.e., /i, u, a/) in languages having a large vowel inventory will be articulated with more extreme tongue positions than their counterparts in languages having a small inventory. As this author suggests (pp. 126-129), empirical support for the density hypothesis has thus far been mixed. And his own articulatory study of Spanish and English gave more mixed results. Specifically, English, with its relatively full vowel space, was expected to show more extreme tongue positions for point vowels and less token-to-token variability than would Spanish, with its 5-vowel phonemic inventory. The first prediction was borne out by the results, however, the Spanish subjects did not show significantly more variable tongue height than did the English subjects.[97]

Another investigation, focusing on coarticulatory variability in vowels, produced findings analogous to those of Flege. Manuel (1990) conducted an

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97 Flege's study examined token-to-token variability of vowels within a single phonetic environment—i.e., *b_ba*—rather than variability as a function of context. The density hypothesis would have it that *all* variability is restricted in languages of crowded vowel inventories.

acoustic study of vowel-to-vowel contextual effects in three languages of the Southern Bantu family. Two of these, Ndebele and Shona, have 5-vowel inventories (with different distributions in the acoustic vowel space), and the third, Sotho, has 7 vowel phonemes. Each language was represented by three male speakers. The prediction that Ndebele and Shona would show greater contextual effects on vowels was found to hold true for the vowel /ɑ/, but not for the vowel /e/, for which none of the languages exhibited appreciable variation. Manuel concluded from her results that the distribution of the vowels of a language within the phonetic space places a ceiling on the amount of contextual variability which is tolerated, but that it does not *determine* it. She characterized the contribution of inventory density to contextual variation in these terms: "... minimally phonemes must have some audible, distinctive output, and ... languages are free to restrict the output of particular phones even further." (p. 1294)

Manuel's conclusions in this regard might perhaps be applied to Flege's results as well. That is, if Spanish vowels show no more token-to-token variability than those of English, that finding might be interpreted as one more indication that, while density of inventory may place upper limits on the level of variability which is tolerated in a language, other factors appear to

be operative as well. It is presumably the result of these that English /u/ varies so much more as a function of environment than does /i/.

The above notwithstanding, this brief review of the density hypothesis suggests that its predictions concerning coarticulatory effects in French and English would likely show less homogeneity from vowel to vowel than do those stemming from Delattre's modes. In contrast to the latter theory, the density hypothesis should predict, for example, no more contextually-induced F2 variability in the English vowel /ɔ/ than in its French counterpart.[98] With regard to the high vowels, while a purely phonemic conceptualization of the vowel spaces of the two languages might lead to a prediction of greater variability for both /i/ and /u/ of English than for the /i/, /y/ and /u/ of French, if one pays heed to what has been discovered concerning the phonetic nature of these vowels, the predictions are altered slightly. Rochet's (1995) results for high-vowel perception suggest that French /u/ and /y/ occupy approximately the same F2 space as the single phoneme /u/ in English, while French and English /i/ are quite similar.

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98 A superposition of the English vowel space as defined by the formant values given by Peterson and Barney (1954) over the French vowel space defined by Delattre's (1969) values shows slightly less distance between English /ʌ/ and /ɔ/ than between French /œ/ and /ɔ/. However, J. Ohala (personal communication) has noted that much of the literature on the density hypothesis assumes that vowels can be completely characterized by single formant values; he suspects that accurate interpretation of results to be found with respect to non-corner vowels such as /ɛ/ and /ɔ/ will need to give attention to dynamic spectral cues (e.g., Nearey, 1989).

These findings lead to the prediction that variability as a function of consonantal context in French /y/ and /u/ will be significantly smaller than that in English /u/; by contrast, contextual variability in French /i/ might not be significantly different (smaller or greater) from that observed for English /i/. Indeed, the low F2 differences found between the various consonantal environments for English /i/ by Stevens and House (1963) and by Ohde and Sharf (1975) would suggest that lower undershoot values might be difficult to find.

Previous Research

No articles encountered have treated the issue of contextually-induced effects on vowel spectra for French. Still, results from a few published studies dealing with the articulatory dimensions of coarticulation in French may serve to shed a little light on English-French differences and on the predictions suggested by the two theories discussed above. These studies are considered in this section.

Benguerel and Cowan (1974) measured the lip protrusion gestures of six native speakers of French as they pronounced sequences containing the rounded vowels /u, y/ in various environments. Among other results, they

found that in strings such as *sinistre structure* /sinistrstryktyr/,[99] the upper lip protrusion gesture for the first /y/ began during or before the first consonant of the preceding 6-consonant cluster. In a similar vein, Benguerel et al. (1977a) conducted a fiberscopic study of velar coarticulation in a single male speaker of French. They found that in the sequence *quatorze frangines* /katɔrzfrãʒin/, the lowering of the velum began during the articulation of /z/ in anticipation of the nasal vowel, and that nasal airflow began during the /f/ (see also Benguerel et al., 1977b). These articles might easily be interpreted to provide a degree of support for Delattre's notion of vocalic anticipation, however, with no cross-language contrasts established, it is impossible to assert that English coarticulation gestures might be different.[100]

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99 Benguerel and Cowan note (p. 45) that subjects tended to insert /ə/ after the /r/ of *sinistre* and that the avoidance of this required some practice.

100 Daniloff and Moll (1968) reported finding that lip protrusion in English began at or before the onset of the first consonant of a 4-consonant cluster preceding /u/. However, Benguerel and Cowan (1974: 42) advise caution in accepting these findings at face value, for in all tested strings having clusters of 4 consonsants, the final consonant was /r/. Wanting to be sure that observed rounding was due to anticipation of the following vowel, Daniloff and Moll measured rounding separately (in unrounded environments) for the consonants used; they found that, for /r/, lip protrusion was "small and inconsistent"; one of six samples of /l/ showed protrusion; none of the other consonants did. While in the case of /l/, it is tempting to conclude that the single instance of rounding was an accident, one might be more reluctant to dismiss the importance of the feature in /r/ (Ladefoged (1982: 267) estimates English /r/ to have 60% of maximum roundedness). It may be prudent then to conclude that lip rounding has been observed to begin at or before the onset of the first consonant of a 3-consonant cluster preceding /u/. Still, however the results are to be interpreted, these two studies provide no point of comparison for anticipatory lip-rounding in English and French. And, of course,

Two investigations of the effects of vowels on consonants bear mention in this review. Gibbon et al. (1993) investigated articulatory contextual effects on the consonants and clusters of /VklV/, /VlV/, and /VkV/ sequences in six European languages. Each language was represented by three speakers. Among the findings from this study was that French was one of the languages in which /k/ was more fronted in the /a_i/ environment than in the /i_a/ environment, while English showed the opposite pattern.

Analogous results to those above were obtained in a study conducted by Hoole et al. (1993). These researchers used electropalatography and acoustic analysis to investigate the coarticulatory effects of vowels on the fricatives /s/ and /ʃ/ in English, French and German. There were two speakers for each language. Results showed that, while, in English and in German, the greatest coarticulatory effects on the fricatives came from the preceding vowel, the French subjects were split in this regard, with one favouring carryover effects, and the other showing more anticipatory effects. Furthermore, the French fricatives did show greater variability as a function of surrounding vowels than those of the other two languages. Studies such as these, with small numbers of subjects, fail to yield firm conclusions about

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since English has no distinctive nasal vowels, it could not be the object of a study parallel to that of Benguerel et al., (1977a).

contrasting patterns in languages. However, they contain a hint of the possibility of a French preference for open syllables (as suggested by the modes), with consonants binding themselves more tightly to following vowels than to preceding ones. It could be suggested as well that, given a postulated close bond between a consonant and a following vowel, and a postulated preeminence and stability of vowels, greater effects of vowels on consonants might reasonably be predicted for French than for English within the framework of the modes—that is, if vowels are to maintain their integrity, perhaps consonants could be expected to vary to a greater degree as a function of their vocalic surroundings. On the other hand, the authors of this latter study have interpreted the finding with regard to greater overall coarticulatory effects of vowels on fricatives in French than in the other two languages as providing tentative support for the density hypothesis, since the contrasted languages both have more voiceless lingual fricatives than French (i.e., /θ/ in English, /ç, x/ in German). However, they caution that "the voiceless fricatives are not an ideal field for testing a consonantal version of the density hypothesis with respect to these languages" (p. 258).

Finally, a single contrastive investigation of contextual effects on French and English vowels has come to this author's attention. Here, Ní Chasaide and Gobl (1993) observed the effect of voiced and voiceless stops on the

voicing source of interconsonantal vowels in German, English, Swedish, French, and Italian. The consonantal environments comprised all permutations of /p, b, f, v/. Each language was represented by at least 5 speakers. Among the findings of this study were that German and French vowels "showed the least variation in voicing characteristics as a function of the following context", and that "[t]he nature of the initial consonant had little differential effect [on the vowel] in French or Italian." (p. 325) Otherwise stated, French was unique in showing little voicing effect on vowels from either preceding or following consonants. While these results do not lead to conclusions of any kind concerning a density hypothesis, of course, they might be taken as support for the notion of the preeminence of French vowels held within the framework of the modes.

EXPERIMENTAL HYPOTHESES

Two theories have been considered above, which suggest similar, but not identical predictions with regard to some of the outcomes of the present study. Both have found a degree of support in the literature considered; however, neither has strong support and neither accounts for observed differences between English /i/ and /u/ with respect to contextually-

induced acoustic variability. Accordingly, while these theories are borne in mind for the formulation of hypotheses for this study, where they conflict with previous findings for English, the findings are accorded priority.

Acoustic Analysis

Both the theory of the modes and the density hypothesis point to the following predictions for the French and English rounded high vowels:

1. The French rounded vowels /y/ and /u/ will vary significantly less along the F2 dimension as a function of consonantal surroundings than the corresponding English vowel /u/.

As has been noted above, the modes would also predict less variability due to environment for French /i/ than for its English counterpart. If mere numbers of high-vowel phonemes were considered, the density hypothesis would make the same prediction. However, the acoustical studies noted above suggest that, for reasons not understood at this point, English /i/ is a vowel of relatively stable high F2 values.[101] In this light, it seems unlikely that French /i/ could show less acoustic variability, and the following hypothesis is adopted:

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101 See Lindblom and Studdert-Kennedy (1967: 838) for a similar conclusion concerning English /ɪ/ in contrast to /ʊ/.

2. French /i/ will not show a significantly different degree of contextually-induced variability than will English /i/.

Perceptual Test—Synthetic Signals

The postulated vocalic stability under the mode theory and the density hypothesis make the same prediction concerning findings in the perceptual test using synthetic signals. This is expressed in the following hypothesis:

3. The French /i-y/ and /y-u/ perceptual boundaries will vary significantly less along the F2 dimension as a function of consonantal surroundings than than the English /i-u/ boundary.

Perceptual Test—Natural Signals

In themselves, of course, neither the modes nor the density hypothesis can suggest predictions concerning how French listeners will categorize the vowels of Canadian English speakers. However, in light of the findings of Rochet (1995) with regard to the perceptual spaces occupied by the English and French high vowels, if the preceding predictions concerning categorization boundaries are borne out, one would expect as well to see empirical support for the following hypotheses:

4. English /i/ will be identified by French listeners as /i/ regardless of consonantal context.

5. English /u/ will be identified by French listeners as /u/ or /y/, more often as the former in /bVb/ and /gVg/ contexts, more often as the latter in /dVd/ contexts.

RESULTS AND DISCUSSION

ACOUSTIC ANALYSIS

English Coarticulatory Effects

In accordance with the procedures outlined in the previous chapter, the speakers of English provided ten tokens each of the items /bub/, /dud/ and /gug/, and five each of /bib/, /did/ and /gig/. With twelve speakers, this yielded a total of 360 /u/s and 180 /i/s. A number of items (13 of 360 /u/s, 8 of 180 /i/s) had to be discarded. In a few cases, paper shuffling and the like produced noise that prevented the finding of a reliable F2 value. In other cases, the presence of hoarseness or trembling in the speaker's voice led the author to judge that a given token was not representative of the subject's normal speech. In the case of the vowel /u/, in the worst instance, such problems were responsible for the loss of three tokens of /gug/ from one speaker. Additionally, an unforeseen intrusion into the recording room caused the loss of 4 items for another speaker (2 of /bub/, 1 each of /dud/ and /gug/). In no case was there need to discard more than one of a subject's five /i/ tokens. It was judged that in all cases the remaining signals provided

an adequate sampling of each speaker's vowels; these were used to compute the mean F2 value for each speaker for each vowel in each context.[102]

A repeated measures analysis of these means revealed a significant main effect for Context [$F(2, 22) = 257.775$; $p < .0001$], and for the Vowel-by-Context interaction [$F(2, 22) = 105.152$; $p < .0001$].[103] Of most central interest was the finding from F-tests for comparison of means (Ferguson and Takane, 1989: 321-325) that 4 of 6 pairwise contrasts of vowels-within-contexts were significant beyond the .05 level after Bonferroni adjustment ($\alpha = .05/6 = .0083$). Results of these are shown below in Table 4.

TABLE 4: Comparisons of means from the interactive effect of Vowel and Context in the analysis of F2 mean values of English /i, u/. Probabilities which show significant difference (at $\alpha = .05/6 = .0083$) are marked with "*".

Comparison	F(1, 22)	p
/bib/ vs. /gig/	2.025	= .1688
/bib/ vs. /did/	14.439	= .0010*
/gig/ vs. /did/	5.650	= .0266
/bub/ vs. /gug/	70.573	< .0001*
/bub/ vs. /dud/	575.529	< .0001*
/gug/ vs. /dud/	243.030	< .0001*

102 The raw data from the acoustic analyses are presented in Appendix C. In addition, while only F2 values have been analyzed here, values for F1 and F3 were taken from 5 tokens of each speech item (where available) for a subset of the speakers. Means and standard deviations of these measurements are also presented in Appendix C.

103 In order to avoid encumbering the text of this report with details of little interest (e.g., the significance of the main effect of vowel in the present instance), only results which are central to the focus of this study and those required by statistical procedure are reported.

The F2 means and standard deviations, separated by sex of speaker, are given in Table 5 and plotted in Figure 2.

TABLE 5: F2 Means (in Hz) and Standard Deviations for the vowels /i, u/ produced in three consonantal environments by male and female speakers of Canadian English.

	Females		Males	
	Mean	St. Dev.	Mean	St. Dev.
/bib/	2626	75	2339	213
/gig/	2663	102	2351	204
/did/	2708	82	2384	194
/bub/	1338	87	1055	87
/gug/	1475	73	1185	93
/dud/	1710	105	1440	74

Figure 3 compares these results for male speakers with those found by Stevens and House (1963), and by Ohde and Sharf (1975) and reported in Tables 1 and 2 (pp. 84 and 87, above). The present values for /u/ all lie between those found in the two earlier studies, lying much closer to the higher values reported by Ohde and Sharf than to the lower ones of Stevens and House. Present values for /i/ are relatively high. Still, the broad coarticulatory trends from these three studies are identical, as is indicated by the near-parallel nature of the lines: in all three studies, as one moves from labial to velar to alveolar environments, one sees a considerable rise in the value of F2 for English /u/; and, though significance was found for the

/bib/-vs.-/did/contrast, all contextual effects for the vowel /i/ are very small in comparison to those for /u/.

Figure 2: F2 means and 1-standard-deviation error bars for English /i, u/ produced by male and female speakers in three consonantal environments.

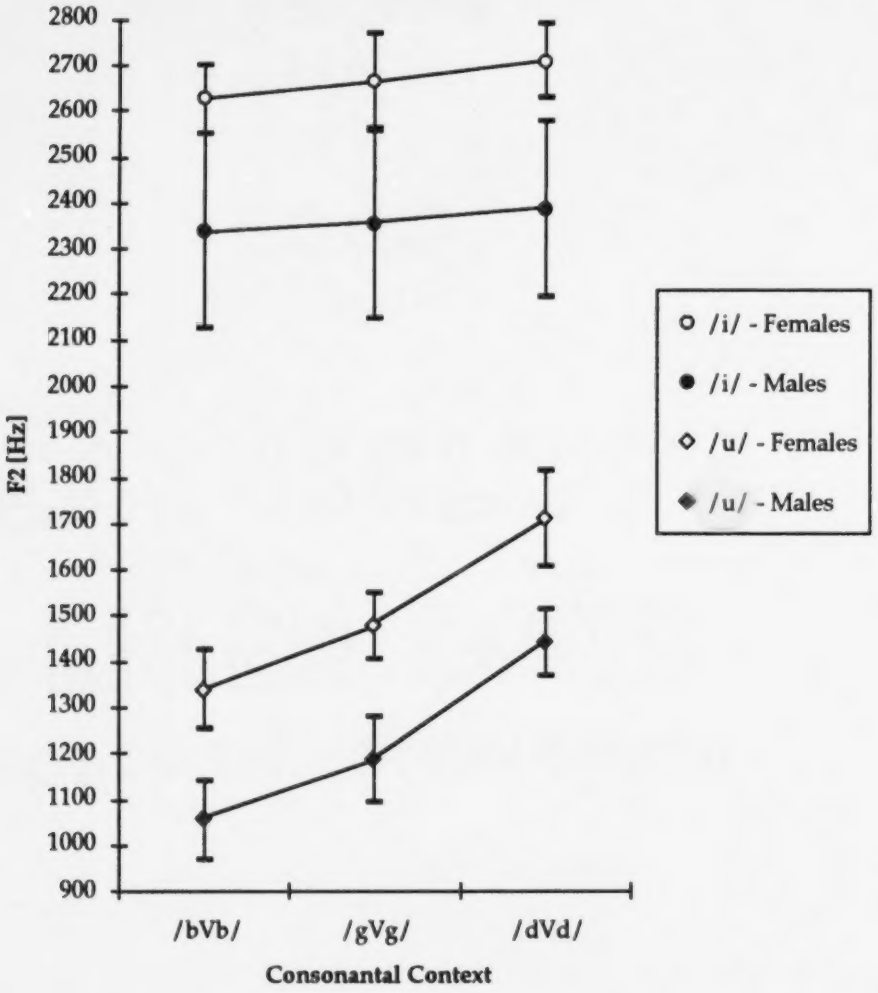


Figure 3: Comparison of the F2 means of English /i, u/ produced in 3 environments by male speakers of English, as reported in three different studies: *Pr* (the present study), *OS* (Ohde and Sharf, 1975), *SH* (Stevens and House, 1963).

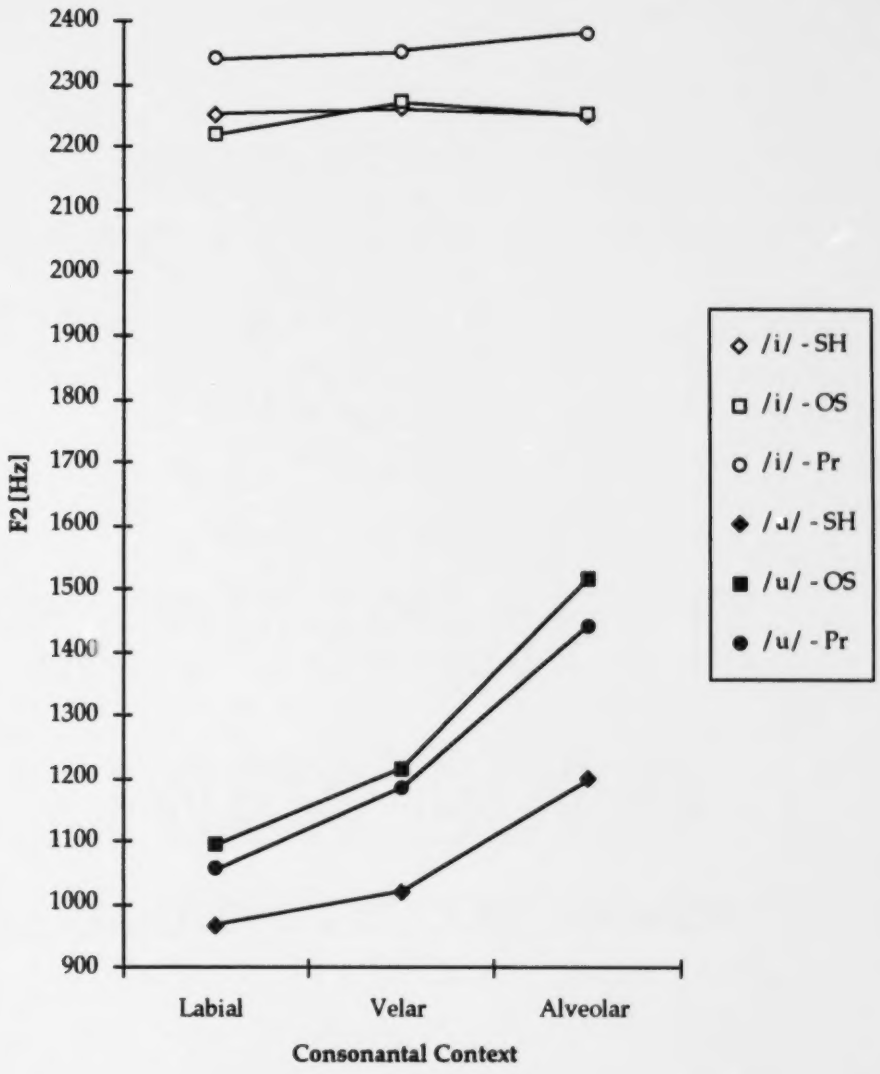
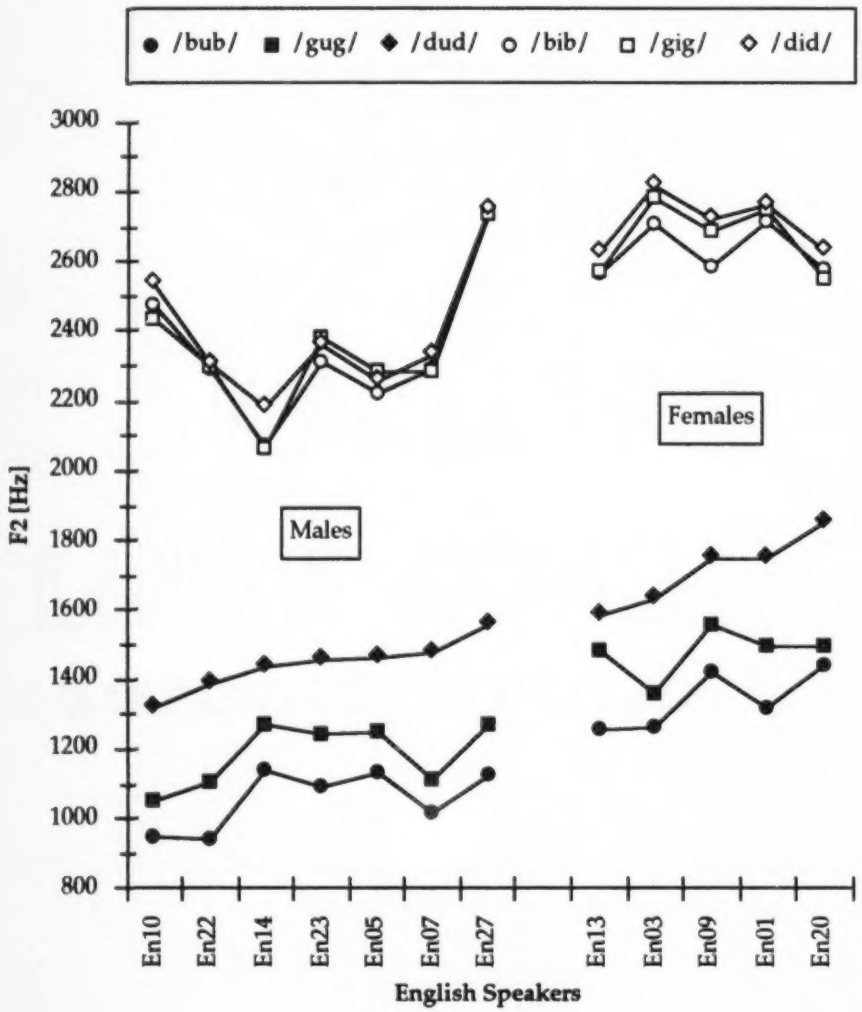


Figure 4, below, shows the vowel-within-context F2 means of each English speaker. Where the vowel /u/ is concerned, means from individual speakers reflect the pooled trends faithfully. No single subject's mean from the present

investigation stands as an exception to the pattern; all show values for the velar context to lie between those for the labial and the dental environments, and all show much smaller contextual effects for /i/ than for /u/.

Figure 4: F2 means for English /i, u/ in three consonantal environments. Ordering is according to increasing values for /dud/, which also divide speakers according to sex.



For the vowel /i/, however, while mean F2 values in labial context are always below those in alveolar context, the means for velar context show less consistency from speaker to speaker.

In accord, then, with the findings of previous studies, the present results show the effect of consonantal environment upon the spectral characteristics of English /u/ to be large. As for the case of the vowel /i/, while the alveolar environment has been shown to differ significantly from the labial context, the magnitude of this effect is small.

French Coarticulatory Effects

Each of the French subjects provided ten tokens each of the items /bub/, /dud/, /gug/, /byb/, /dyd/, /gyg/, /bib/, /did/ and /gig/. Statistical analysis was completed as for the English data. As was the case there, the main effect of Context was significant [$F(2, 8) = 21.737$; $p = .0006$], as was the Vowel-by-Context interaction [$F(4, 16) = 3.452$; $p = .0324$].[104] Results of the F-tests for comparison of means in this interaction are shown in Table 6. With an adjusted α-level of .0055 (i.e., .05/9) for multiple tests, two of these nine comparisons reach significance.

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104 Using the Hunyh-Feldt adjustment factor for low sample sizes, the *p*-value for this interaction is as reported, however, with Greenhouse-Geissler it rises to .0578, and the effect narrowly misses significance.

TABLE 6: Comparisons of means from the interactive effect of Vowel and Context in the analysis of F2 mean values of French /i, y, u/. Probabilities which show significant difference (at $\alpha = .05/9 = .0055$) are marked with "*".

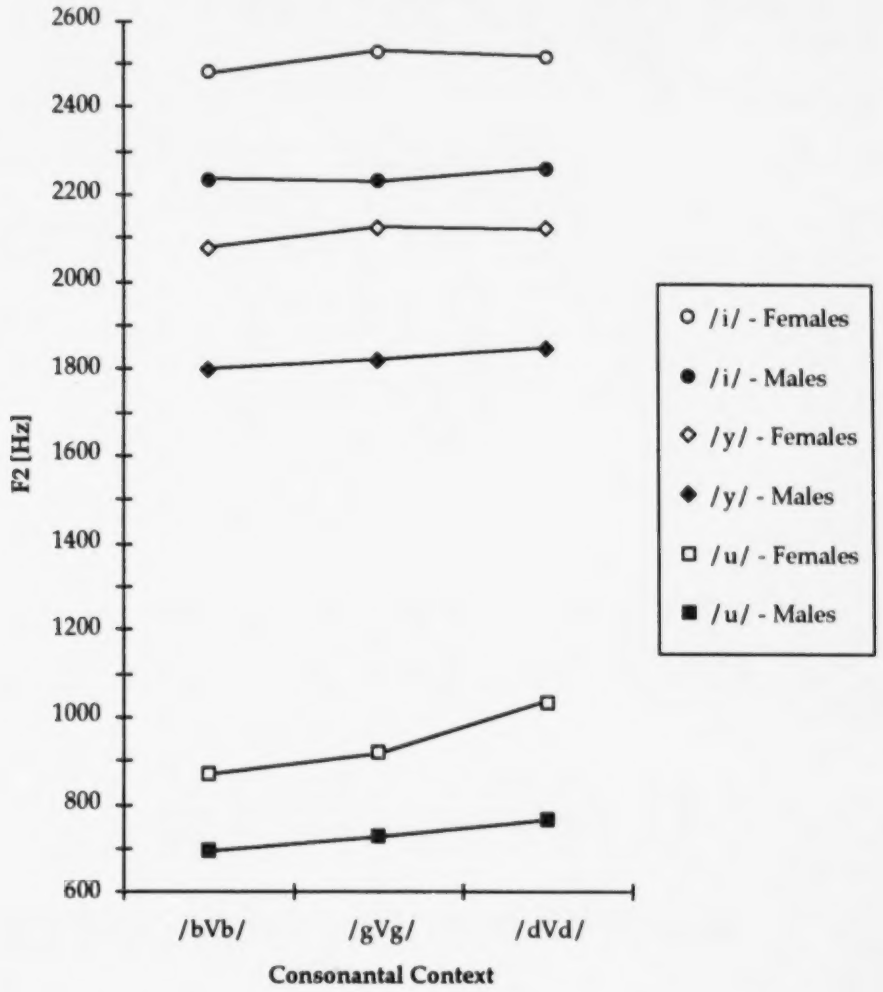
Comparison	F(1, 16)	p
/bib/ vs. /gig/	1.839	.1939
/bib/ vs. /did/	2.712	.1191
/gig/ vs. /did/	0.084	.7751
/byb/ vs. /gyg/	3.532	.0785
/byb/ vs. /dyd/	6.102	.0251
/gyg/ vs. /dyd/	0.349	.5628
/bub/ vs. /gug/	4.965	.0406
/bub/ vs. /dud/	38.680	< .0001*
/gug/ vs. /dud/	15.930	.0011*

Means and standard deviations for each vowel in each context, separated by sex of speakers, are listed in Table 7. The means are plotted in Figure 5.

TABLE 7: F2 Means (in Hz) and Standard Deviations for the vowels /i, y, u/ produced in three consonantal environments by male and female speakers of French.

	Females		Males	
	Mean	St. Dev.	Mean	St. Dev.
/bib/	2476	91	2236	251
/gig/	2525	87	2232	264
/did/	2516	94	2261	257
/byb/	2077	22	1794	178
/gyg/	2124	88	1820	158
/dyd/	2126	77	1848	173
/bub/	866	73	692	66
/gug/	918	53	729	4
/dud/	1033	50	763	11

Figure 5: F2 means for French /i, y, u/ produced by male and female speakers in three consonantal environments. (Standard Deviation error bars have been omitted, since their overlapping makes them difficult to interpret.)



While the F2 means of /gug/ and /dud/ are both revealed to differ significantly from that of /bub/, it appears clear from Figure 5 that contextual effects for French /u/ are substantially smaller than those for English /u/.

Figure 6: F2 means for French /i, y, u/ in three consonantal environments. Ordering is according to increasing values for /dud/, which also divide speakers according to sex.

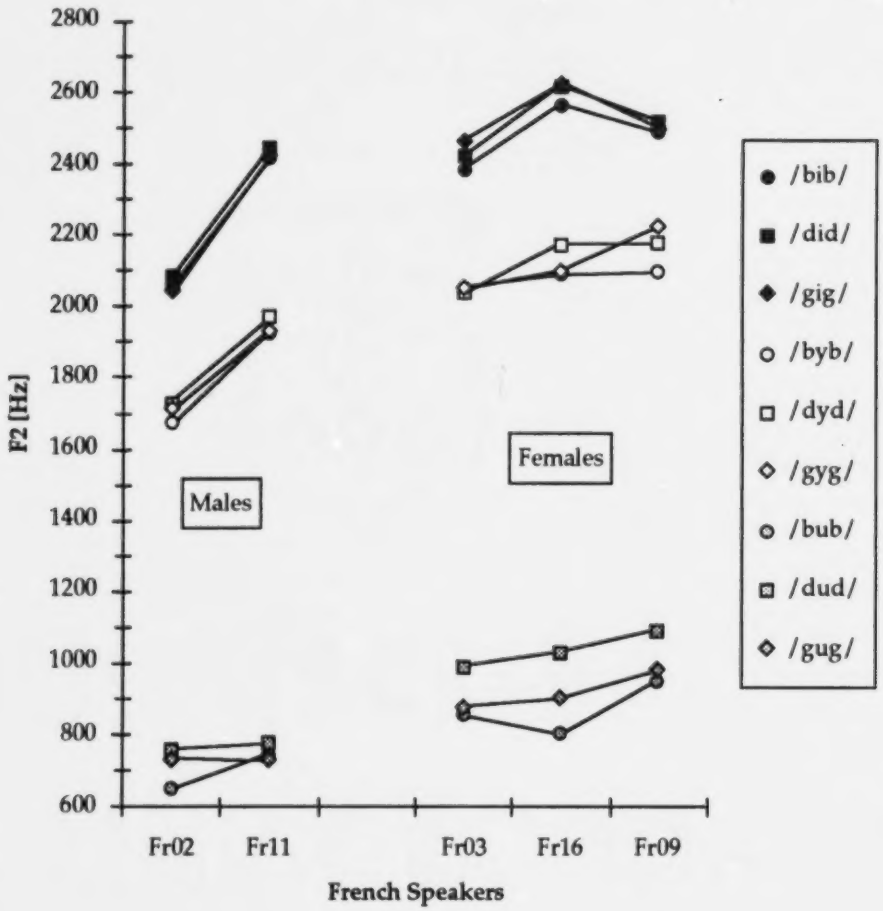


Figure 6, above, shows the F2 means for individual speakers. While coarticulatory effects are generally small, the means for the various contexts display a pattern similar to that observed among English subjects for the vowel /i/: while /bVb/ values remain generally lower than those for /dVd/, the velar context appears to have varying effects from speaker to speaker.

French and English Effects Compared

The testing of Hypotheses 1 and 2 involves three separate analyses: one in which English /i/ and French /i/ are compared, two more in which English /u/ is equated first with French /u/, then with /y/. For these, the mean F2 values for each subject for each consonantal environment were submitted to a repeated measures ANOVA with one between-subject factor, Language, and one within-subject factor, Context. Here, it is not the main effects of Language or Context which are of interest, but the interaction of Context and Language.

As might have been predicted from consideration of Figures 3 and 5, above, the analysis of English and French /u/s revealed the Context-by-Language interaction to be highly significant [$F(2, 30) = 34.161$; $p < .0001$].[105] Similar results were found for the comparison of English /u/ and French /y/ [$F(2, 30) = 64.187$; $p < .0001$]. These results support the prediction made in Hypothesis 1 that the French vowels /u/ and /y/ would vary significantly less along the F2 dimension than the corresponding English vowel /u/.

Not surprisingly, in light of what has preceded, in the analysis of the /i/s of English and French, neither the effect of Language [$F(1, 15) = .545$;

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105 Group means have been reported above and are not repeated here; however, Figure 7 (p. 138, below) plots their relationships.

p = .4716] nor the interaction of Context and Language [F (2, 30) = 1.282; p = .2922] was significant.[106] The vowel /i/ varies little as a function of consonantal environment in either language. This finding offers support for Hypothesis 2, according to which French /i/ would not show a different degree of contextually-induced variability than English /i/.

Discussion

Several generalizations may serve to tie together the above results of acoustic analyses. First, nowhere does subject-to-subject uniformity in contextual effects reach the level shown for the production of English /u/. While F2 means for /u/ in velar environment always lie between those for alveolar and labial environments, English /i/ between velars may have high, medial, or low values. Similar patterns obtain for the French vowels included in this study, especially /i/ and /y/. This observation accounts for the lack of significance found in within-language comparisons involving the vowel /i/ in velar context. In this, the present results offer support to Ohala's (1974) observation that "velars have little effect on vowel quality",[107] an observation

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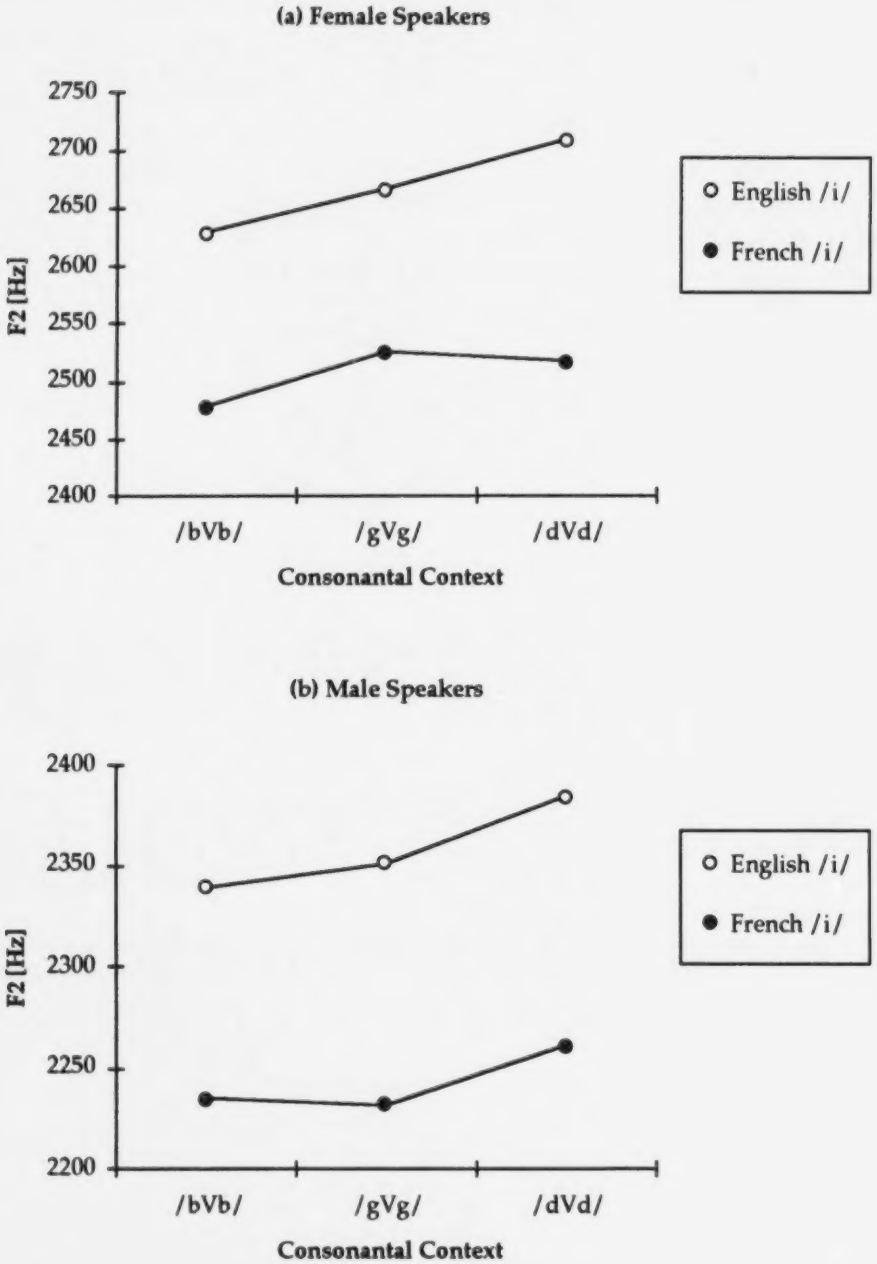
106 See Figure 8; p. 140, for the Context-by-Language F2 means for males and females.

107 The present results have shown velars to have a significant effect on English /u/, but only in comparison to labials and alveolars. Having included no vowels in either isolation or /h_d/ context (to provide "cardinal" values), this study cannot point to conclusions concerning the absolute effects of velars.

which he attributes to the fact that "the lip configuration and the place of articulation of the 'velar' can vary rather freely as a function of the contiguous vowel" (p. 265). However, this generalization appears to characterize the patterns of the *groups* of speakers rather than those of individuals. Velars sometimes appear to have a substantial effect on vowel quality, but that effect is not constant from speaker to speaker. It may be that, for some individuals, salient coarticulatory influences are primarily those of velars on vowels, whereas, for others, they run in the opposite direction.

In line with the results of previous studies (cited above), the present findings show English /i/ to be affected by consonantal environment to a far lesser degree than /u/. Similar observations can be made for French /i/ and /y/—in fact, for these two vowels, the analyses conducted here found no significant effect of any context. This weak effect of environment on the /i/s of the two languages is illustrated graphically in Figure 7, below. The only significant contrast shown in this graph is that of English /bib/ vs. /did/, and that difference is not large, at least not in comparison to the effects seen for English /u/.

Figure 7: F2 means of male and female speakers for English and French /i/ in three consonantal environments.



In both French and English, the largest contextual effects seen in this study are for the /u/ vowels. In French, the dental environment contrasts significantly with those of both velars and labials. In English, all three pairwise comparisons are significant. Figure 8, below, shows the Vowel-by-Context interactions for English /u/ and French /y/ and /u/. Two observations become obvious from consideration of this plot. First, it provides a graphic indication of the fact that English /u/ occupies an acoustic space which falls roughly midway between those of French /u/ and /y/. Secondly, while French /u/ between dental consonants has been shown to have significantly higher F2 values than it has between labials and velars, this shift—roughly twice that seen for English /i/—is only about one third as large as the corresponding shift in English /u/. The result is that, in the latter contexts the English vowel tends toward French /u/, while in the former it is closer to /y/. Thus, from the point of view of acoustics, there appear to be no grounds for claiming that English has an [u], but no [y].[108]

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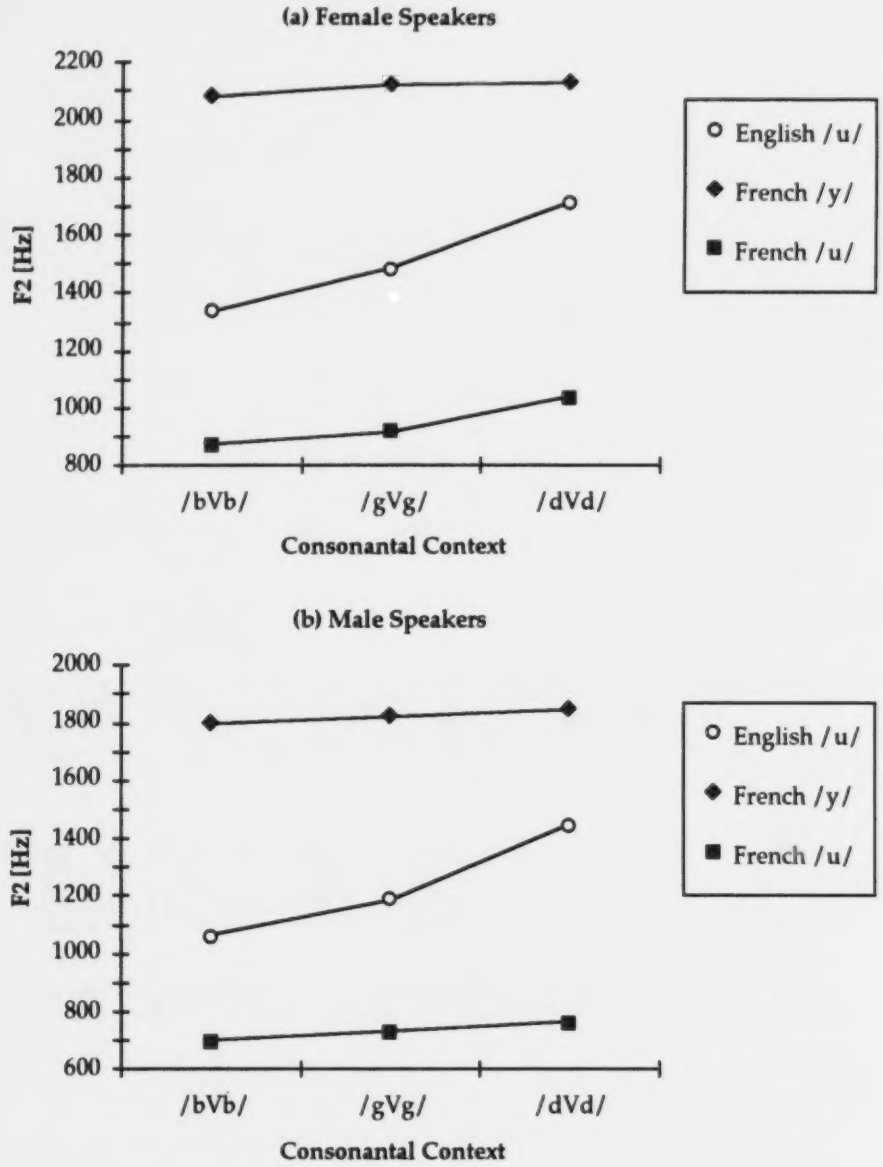
108 An additional point to be taken from these results concerns Matte's (1982) claim concerning the centrifugal nature of French vowels as compared to the centripetal vowels of English (see note 88, p. 111, above). The present findings lend support to that notion where the /u/s of the two languages are concerned: here, French F2 values are much lower than those of English. However, the theory would predict a significantly higher F2 for French /i/ than for English /i/. The lack of significance for the main effect of language in the /i/ analysis shows this not to be the case, at least for the subjects observed here; in fact, there is a non-significant trend in the opposite direction.

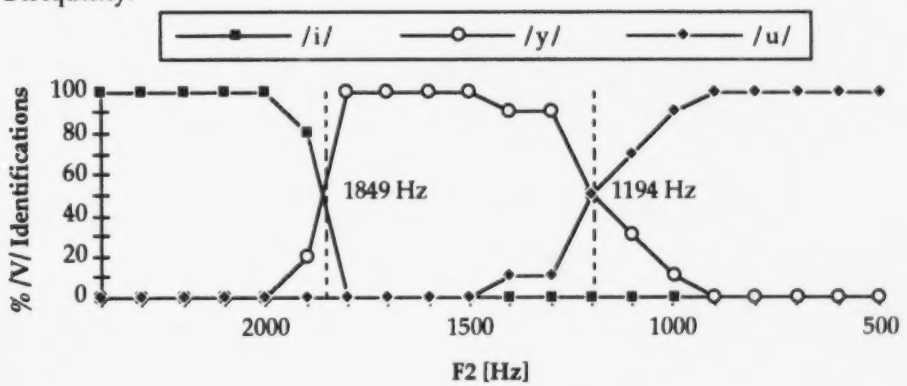
Figure 8: F2 means of male and female speakers for English /u/ and French /y, u/ in three consonantal environments.



PERCEPTION OF SYNTHETIC VOWELS

As is noted in the preceding chapter, each facet of the synthetic-signals perceptual task contained 10 tokens of each of 20 vowels in a continuum varying primarily along the F2 dimension. These 200 vowel tokens were presented to each French and English listener three times, once in each of the consonantal environments /#V/, /bV/, and /dV/. From the output files of each of these tests, the total numbers of /i/, (/y/,) and /u/ responses for the ten tokens of each vowel in the continuum were taken. These values were then used to plot vowel identification functions of the type shown in Figure 9, below.[109]

Figure 9: Typical plot of French vowel categorization proportions as a function of variations in F2 frequency.



109 Appendix D contains the vowel identification plots of all subjects for all consonantal environments, as well as plots for the mean proportions in each environment across all subjects within the two language groups.

The vertical dashed lines in the plot shown in Figure 9 represent the F2 frequency of the vowel boundaries. For the French /y-u/ boundary, this crossover value was derived using the following formula:[110]

$$B_{y\text{-}u} = (\Sigma u / T) \times F_S + F_L$$, where

$B_{y\text{-}u}$ is the value in Hz of the F2 boundary separating /y/ from /u/;
Σu is the total number of /u/ responses in the test;
T is the total number of items in the test (i.e., 200);
F_L is the lowest frequency in the F2 continuum (i.e., 500 Hz); and
F_S is the frequency span of the F2 continuum (i.e., 2400 - 500 = 1900 Hz).

The English /i-u/ crossover value was computed similarly. For the French /i-y/ boundary, then, the following formula was used:

$$B_{i\text{-}y} = (\Sigma y + \Sigma u) \times F_S + F_L$$

It was mentioned in the preceding chapter that, as the result of error, the /bV/ signals had a somewhat different shape from those of the other two series.[111] At one point the shortening of the F2 range of the continua had been contemplated. This abridgement was made only to the /bV/ continuum (without a corresponding reduction in the number of members), and the original form was never restored. The result was that, instead of having a

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110 These formulas for computation of vowel boundaries were provided in personal communication by B. Rochet, who credits them to T. Nearey.

111 This error was noticed only after all subjects, both English and French, had completed all three parts of this perceptual task.

range of 500 to 2400 Hz in steps of 100 Hz, as did the other two, the /bV/ continuum had steps of 75 Hz running from a low of 800 to a high of 2225.

For the computation of boundary values, this new range of 1425 Hz could be easily incorporated into the derivation formulas given above. Yet there remained the concern as to whether the differences between the ranges and/or step sizes might alter the results. In order to investigate this possibility, a new /bV/ continuum was prepared with extended range and step size. The French listeners who had taken the original tests were no longer accessible, however, the same test with the new continuum was administered to 6 of the English listeners. The /i-u/ boundary values yielded in testing on the two different /bV/ continua were submitted to a repeated measures ANOVA. It was found that those from the first test (mean = 1702 Hz; st. dev. = 73) and those of the second (mean = 1740 Hz; st. dev. = 107) did not differ significantly [$F(1, 5) = 1.890$; $p = .2276$]. It was judged on this basis that the effect of the altered form of the original /bV/ continuum was not great enough to preclude the comparison of its boundary values with those yielded by the /dV/ and /#V/ continua.

English Listeners

The procedures outlined above provided an F2-boundary value for each of three environments for each of the twenty-one English-speaking listeners who completed the three parts of this perceptual task. The data for one of these subjects (En18) had to be excluded; the irregularity of two of the identification functions rendered his derived crossover values invalid.

Figure 10 plots the individual boundary values of the remaining twenty listeners. The most striking trait of this graph is the wide divergence in all crossover values of the first four subjects on the left from the others. The highest values of the former subjects do not reach above 1500 Hz, whereas the lowest of the latter listeners do not fall below 1600 Hz. On the basis of this wide gap, it was judged that these four listeners were not reacting to the synthetic signals as they do to normal speech,[112] and their data were excluded from the following analyses.

The boundary values of the remaining sixteen listeners were submitted to a repeated measures analysis with Context as the one within-subject factor. The analysis showed that effect to be significant [$F(2, 30) = 5.836$; $p = .0072$].

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112 In a very quick and informal test, the author (shielding his lips from view) asked three of these four listeners to repeat a token of each of French /i/, /y/, and /u/ in isolation and in /bV/ and /dV/ contexts. In response to all /y/ stimuli, all three subjects produced some form of /u/.

The means and standard deviations under this effect are presented in Table 8 and plotted in Figure 11.

Figure 10: English listeners' F2 crossover values for the /i/-/u/ boundary in three environments. Data from the first four subjects on the left were excluded from the analysis on the basis of their exceptionally low values (see text). For the remaining listeners, grouping is according to maximum-to-minimum ordering of boundary values as labelled. Ordering within groups is by increasing distance between /dV/ and /bV/ values.

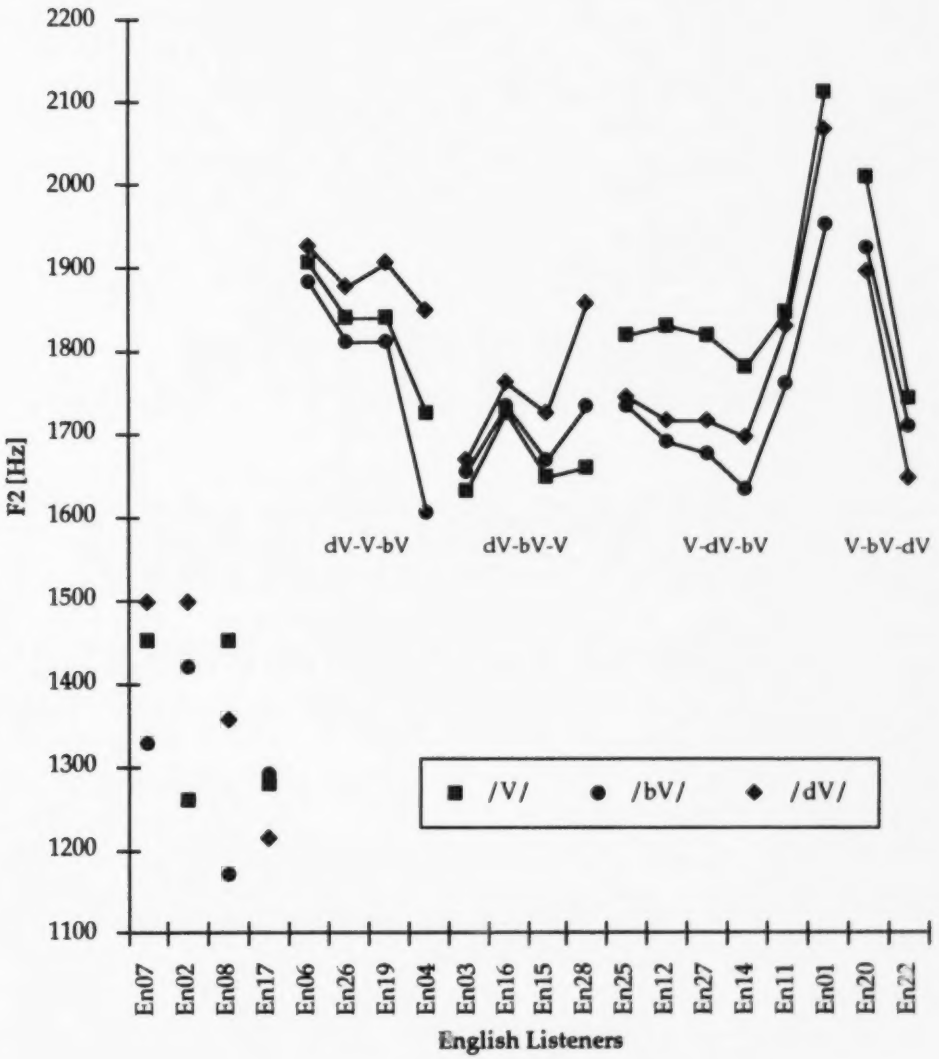
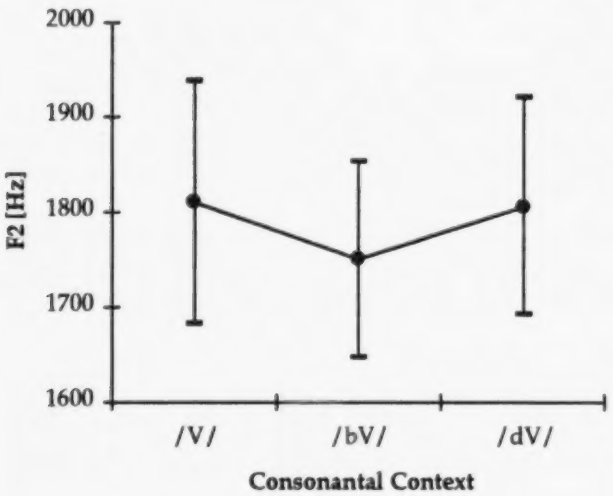


TABLE 8: F2 Means (in Hz) and Standard Deviations for the /i-u/ boundary from the analysis of the perception of synthetic vowels by English listeners.

	Mean	St. Dev.
/#V/	1810	128
/bV/	1749	103
/dV/	1806	114

Figure 11: F2 Means and standard deviation error bars for the /i-u/ boundary in three environments as revealed by English listeners in a synthetic vowel identification task.



As might be guessed from Figure 11, pairwise comparisons (df = 1, 30; $\alpha = .05/3 = .0167$) showed the labial context to differ significantly from the alveolar [F = 8.195; p = .0076] and from the isolated vowel [F = 9.279; p = .0048]. The effects of the latter two contexts did not differ significantly [F = 0.034; p = .8557].

Consideration of the individual values shown in Figure 10, above, in light of these pooled results, yields some interesting observations. While the trend across listeners is for the boundary for isolated vowel to be high (indeed, it has the highest mean value of the three boundaries), only eight of the sixteen retained listeners place it highest. The remaining eight are split, with four giving this boundary a medial placement, and four a low placement. By contrast, the labial-to-alveolar relationship appears much more stable from listener to listener, with all but two subjects having higher values for the /dV/ than for the /bV/ crossover.

French Listeners

Procedures similar to those above provided two F2-boundary values for each of three environments for each of the nine French listeners who completed the three parts of this perceptual task.[113] Figure 12 plots their individual crossover values.

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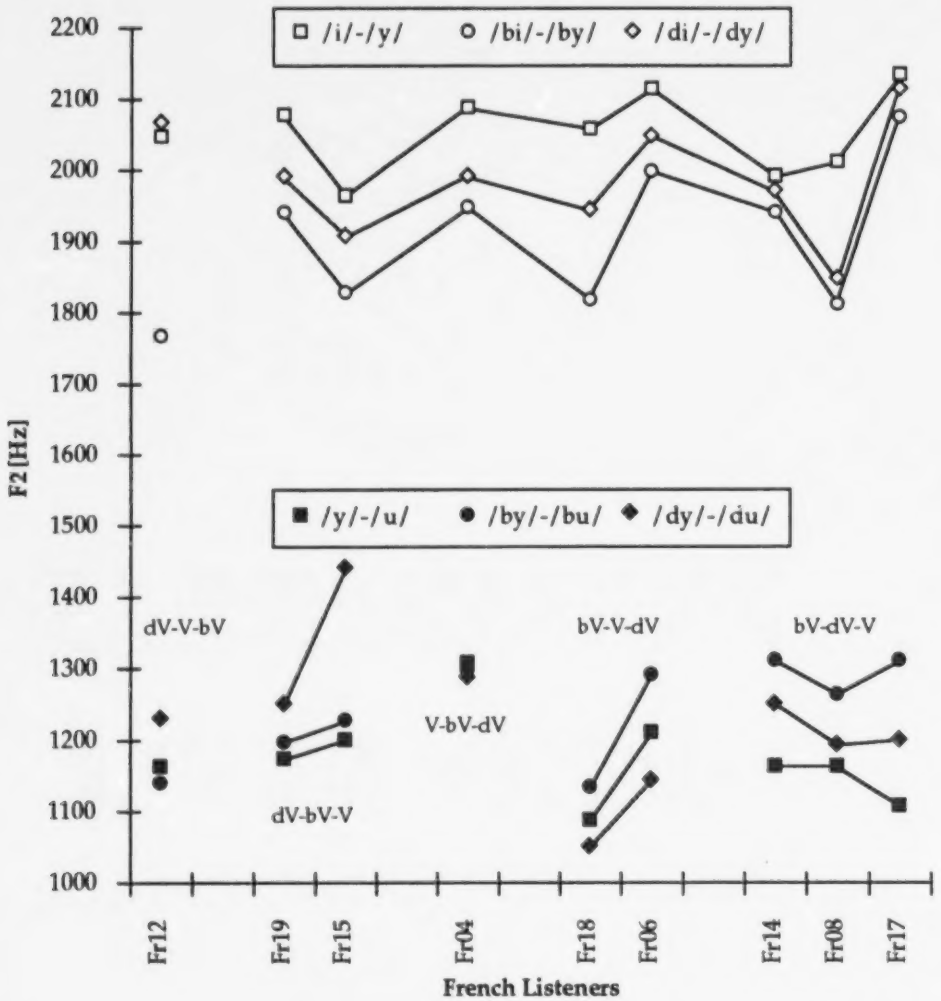
113 As will be seen below, the data of two of these nine subjects were excluded from the analysis of the natural-speech vowel identification test on the basis of the divergence of their perceptual patterns from those of the rest of the listeners. As is shown in Figure 12, the first of these, Fr04, does not set himself apart from the others in the perception of synthesized vowels. Some of the crossover values of the second of these subjects, Fr12 (most notably the large difference between the labial and dental environments for the /i-y/ boundary), might be said to lie on the margins of the body of results, but they are not clearly outliers. The results of both of these listeners were retained for the present analysis.

Figure 12: French listeners' F2 crossover values for the /i-y/ and /y-u/ boundaries in three environments. Grouping is according to maximum-to-minimum ordering of boundary values for the /y-u/ boundary, as labelled. Ordering within groups is by increasing distance between /dV/ and /bV/ values for that boundary.



As this illustration reveals, the /y-u/ crossover shows little listener-to-listener uniformity; in nine subjects, there are five different orders of the three boundaries to be observed. This stands in marked contrast to the /i-y/ boundary, in which there is but a single discontinuity in ordering patterns.

Eight of nine listeners have high crossover values for the isolated vowel context and medial ones for the dental. The one exception has virtually equal values for these two. All nine subjects have the lowest values for the labial environment.

The listeners' crossover values were submitted to a repeated measures analysis with two within-subject factors, Boundary (/i-y/ and /y-u/), and Context (/#V/, /bV/, and /dV/). This analysis showed the interactive effect of Context and Boundary to be highly significant [$F(2, 16) = 26.505$; $p < .0001$]. Subsequent comparisons of means (1, 16 df) showed significance for 4 of the 6 pairings of interest, as is shown in Table 9.

TABLE 9: Comparisons of means (1, 16 df) from the interactive effect of Context and Boundary from the analysis of the perception of synthetic vowels by French listeners. Probabilities which show significant difference ($\alpha = .05/6 = .0083$) are marked with "*".

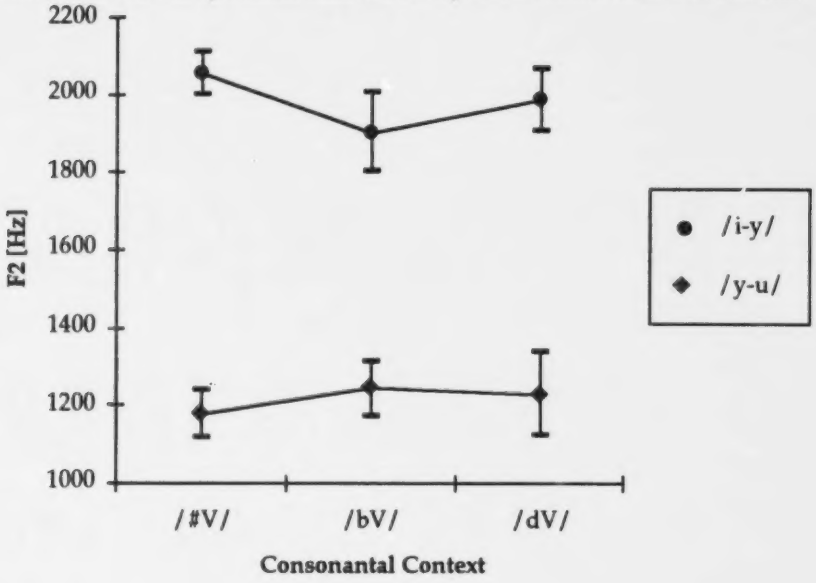
Comparison	F	p
/#i-#y/ vs. /bi-by/	51.297	< .0001*
/#i-#y/ vs. /di-dy/	9.903	= .0062*
/bi-by/ vs. /di-dy/	16.122	= .0010*
/#y-#u/ vs. /by-bu/	9.738	= .0066*
/#y-#u/ vs. /dy-du/	6.040	= .0258
/by-bu/ vs. /dy-du/	0.440	= .5167

The means and standard deviations under this Context-by-Boundary interaction are presented in Table 10 and plotted in Figure 13.

TABLE 10: Means (in Hz) and Standard Deviations of the interactive effect of Context and Boundary from the analysis of the perception of synthetic vowels by French listeners.

	Mean	St. Dev.
/i-y/, /#V/	2054	57
/i-y/, /bV/	1903	101
/i-y/, /dV/	1988	83
/y-u/, /#V/	1177	63
/y-u/, /bV/	1243	71
/y-u/, /dV/	1229	106

Figure 13: Means and standard deviation error bars for two vowel boundaries in three environments as revealed by French listeners in a synthetic vowel identification task.



For the /i-y/ boundary, the labial-dental relationship is as might be expected, with higher values for the /dV/ environment than for /bV/. This relationship appears to be reversed for the /y-u/ boundary, however, with the difference of only 14 Hz, the labial and dental values must be considered

virtually equal. A less expected result is the tendency for the isolated-vowel boundary to have extreme values. Where the /y-u/ crossover is concerned, the /#V/-/bV/ difference is significant; the /#V/-/dV/ difference misses significance ($p = .0258$) after α-adjustment for multiple comparisons. In the /i-y/ boundary, both these contrasts show significant difference.

French and English Listeners Compared

As was the case for the contrastive tests of vowel production, the two tests for Hypothesis 3 entail the comparison of the English /i-u/ boundary with both of the French boundaries. In each case the English and French data were analyzed using a repeated measures analysis of variance with main factors Language and Context. Of preliminary interest here, of course, is the Language-by-Context interaction. In both analyses, this interactive effect was found to be significant: English /i-u/ vs. French /y-u/ [$F(2, 46) = 6.405$; $p = .0035$]; English /i-u/ vs. French /i-y/ [$F(2, 46) = 4.207$; $p = .0210$].

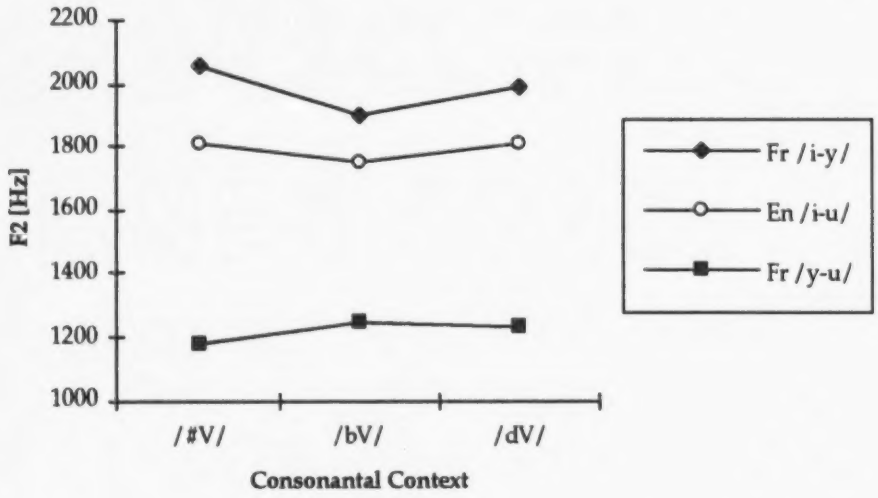
Having found that the effects of context in English are different from those effects in French, one must determine precisely where those differences lie. That is, the question to be answered is whether, for each boundary pairing, the relationship of the /V/-to-/bV/ contexts in French is significantly different from that same relationship in English; the same must

be answered for the /V/-to-/dV/ and /dV/-to-/bV/ relationships. Mean context-to-context differences for these relationships are listed in Table 11. Boundary means are plotted in Figure 14.

TABLE 11: F2 context-to-context differences for English /i-u/ and French /i-y/ and /y-u/ boundaries. Values are in Hz.

Difference	Fr /i-y/	Eng /i-u/	Fr /y-u/
/#V/ - /bV/	151	61	-66
/#V/ - /dV/	66	4	-52
/dV/ - /bV/	85	57	-14

Figure 14: Mean F2 values for one English and two French vowel boundaries in three environments.



While Table 11 gives an idea of which language-to-language differences are salient, the precise determination of which of these relationships show significant difference required that the data be submitted to a multivariate

analysis of variance.[114] The results of the individual pairwise comparisons from these analyses are shown in Table 12.

TABLE 12: Interactive effects of Language and Context in the high vowel boundaries of English and French. Each line compares the contextual effects listed for the French boundary named and the English /i-u/ boundary. Probabilities which show significant difference ($\alpha = .05/6 = .0083$) are marked with "*".

French Boundary	Contextual Comparison	F	p
/i-y/	/V/ vs. /bV/	8.862	= .0067*
/i-y/	/V/ vs. /dV/	3.352	= .0801
/i-y/	/dV/ vs. /bV/	0.808	= .3779
/y-u/	/V/ vs. /bV/	17.266	= .0004*
/y-u/	/V/ vs. /dV/	2.064	= .1642
/y-u/	/dV/ vs. /bV/	3.752	= .0651

Hypothesis 3 predicted that both French vowel boundaries would vary less as a function of consonantal surroundings than the English /i-u/ boundary. That hypothesis does *not* find support in the present results. No significant English-French difference was found for four of the six comparisons. A fifth comparison (the /V/-/bV/ contrast in the French /y-u/ boundary) shows significant difference, not because the magnitude of their shifts differ—their absolute values are virtually equal—but because the shifts are in the opposite direction. Finally, that same contrast in the French /i-y/

114 The author gratefully acknowledges the assistance of T. Taerum, statistical consultant with Computing and Network Services at the University of Alberta, in the conducting of these analyses.

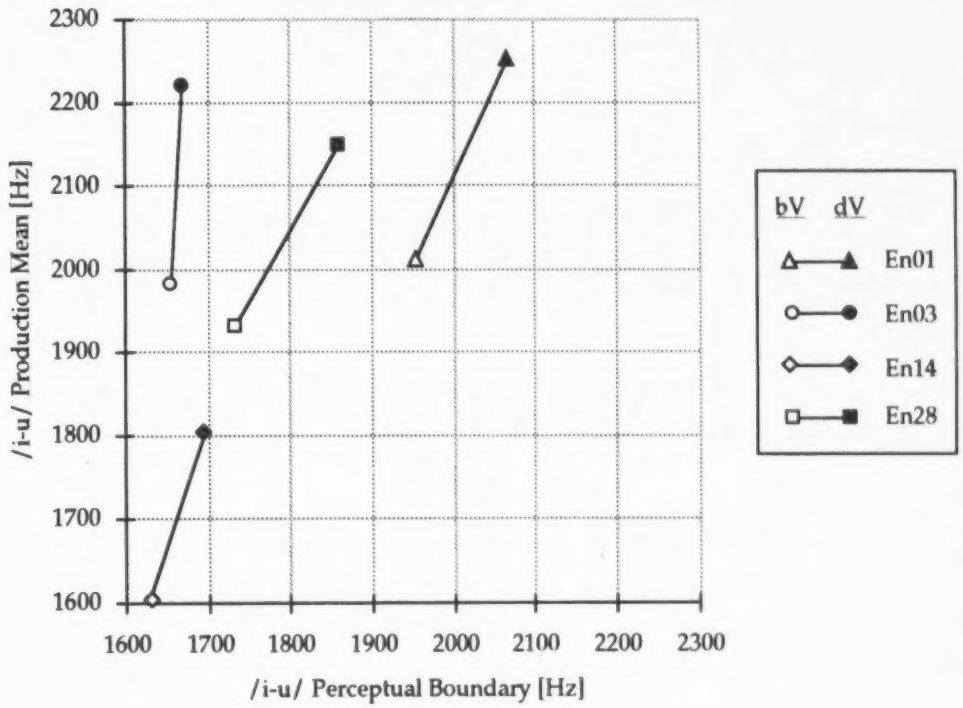
boundary reaches significance because the French boundary varies *more* as a function of context than the English one.

Discussion

One issue which must be treated in light of the results of these vowel identification tests is the relationship between speech production and perception. Due to the designs of the tests used here, as well as to a temporal gap between various administrations of the tests, this issue cannot be explored as fully as might have been preferred. No French subjects provided both perceptual and acoustic data. Only five English subjects provided both, and one of these was among those who, because of their very low F2 values for the /i-u/ boundary, were excluded from consideration. In addition, only two consonantal environments, the alveolar and labial, were common to both tests. Still, one can get a coarse idea of what kind of relationship there exists between the perceptual and acoustic patterns of the four English subjects for these two consonantal environments. As perceptual data, we have the /bi-bu/ and /di-du/ boundary values for each subject; as acoustic data, the /bib-bub/ and /did-dud/ F2 means provide values to be paired with those. These points are plotted on a scattergram in Figure 15. The first observation to be made on the basis of consideration of this scatterplot is that there is a

positive correlation between the perceptual and acoustic trends in the speech behaviour of these four subjects.[115] The second observation is that, in all cases, contextual effects are far greater in vowel production than in perception. This is shown by the fact that all connecting lines are steep, having a slope value substantially higher than 1.

Figure 15: English /i-u/ boundary values plotted against /i-u/ F2 production means in two consonantal contexts for four Canadian English subjects.



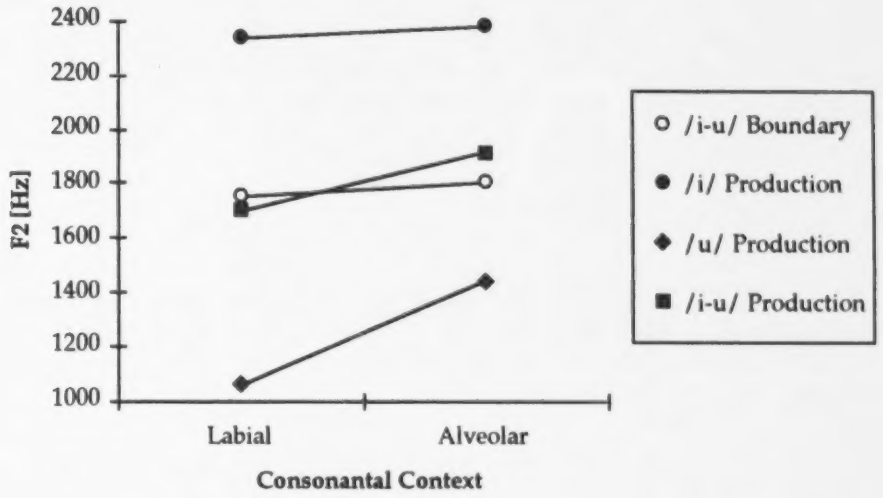
115 Of course, it is pointless to compute correlation coefficients, because, with only two paired scores per subject, the only possible values are +1, 0, and -1. It is clear from Figure 15 that this group shows four positive values.

It is true, of course, that the mean of F2 values of /i/ and /u/ is not the only acoustic parameter against which to plot the boundary values; perceptual patterns might more faithfully reflect acoustic trends in /i/ or /u/ alone. A slope value nearest to 1 indicates the strongest relationship between perception and any acoustic parameter chosen. The slope values for the crossover scores of these four subjects, then, were also calculated using F2 production values for both /i/ and /u/ alone. It was found that, for one subject, En14, coarticulatory effects in /i/ alone provided the closest match with his perceptual compensation. Two others, En28 and En01, show the best slope value using the /i-u/ production mean; however, as is shown in Figure 15 their slopes here are still quite steep. This suggests that their perceptual trends provide compensation for somewhat greater displacement than is present in their production of /i/, but substantially less than in their production of /u/. The fourth subject, En03, shows a steep slope in all cases; her perceptual patterns do not provide a very faithful reflection of any aspect of her vowel production. In no case, then, did perceptual shifts match the displacement shown for production of /u/.

Across all English subjects who provided data for this study, there is close concordance between the perceptual shift in the /i-u/ boundary and the acoustic shift in the production of the vowel /i/. The mean F2 production

value for this vowel in labial environment is 57 Hz lower than that in alveolar environment; the corresponding perceptual adjustment is 60 Hz. Figure 16 plots the mean boundary values and the mean acoustic values for production of English /i/ and /u/, as well as of the average of the latter two.[116]

Figure 16: English /i-u/ boundary values for all listeners and F2 production means for /i/, /u/ and the /i-u/ mean in two consonantal contexts for male speakers.



The close match between the perceptual pattern and that of the production of /i/ is reflected in the almost parallel nature of their two functions in the illustration. It was noted above that Ohala and Feder (1987) found an /i-u/ boundary shift of 75 Hz from /Vdə/ to /Vbə/ environments, and accounted for it as a factoring out of "the elevated F2 that alveolar consonants produce

116 Since boundary values were determined from responses to signals having values appropriate for a male speaker, these relational plots show production values from male subjects only.

on back vowels" (p. 121). Given the smaller acoustic shifts effected on vowels by following consonants, that may have been the case. In the present instance, however, on the surface at least, it would appear that listeners were compensating for the lowered F2 that labials produce on /i/, and that they were making little allowance for the larger effects of alveolars on /u/. Still, this cannot be taken as a firm conclusion. As will be seen below (see pp. 163-165), there is reason to believe that the testing procedures used here may have produced results which underestimate the degree of perceptual compensation for coarticulatory effects which English listeners make in their vowel categorizations. It may well be that a different test might reveal perceptual shifts greater than those found in this study.

Bearing in mind the preceding *caveat*, one might note tentatively that the present results are in line with Nearey's (1989) finding of "perceptual compensation effects [which were] reliable, even if of limited magnitude" (p. 2105). They may also fall into line with a proposal of Van Son (1993a), who, following Whalen's (1991) notion of "planned" coarticulation, has hypothesized (see pages 111 and 129) that listeners do not compensate perceptually for such contextual effects, but only for undershoot which is attributable to articulatory constraint. If the small degree of undershoot observed in the production of English /i/ represents the product of

limitations of the articulatory apparatus, then the difference between that and the much larger degree of undershoot in /u/ may constitute the part of it which is planned. If that is the case, the present findings offer support to this hypothesis. Whatever may be the eventual resolution of this issue, it must be noted here that a perfect match between vowel perception and production will never be found. For to each boundary in perception, there correspond two functions in production. In the case of English /u/ and /i/, for reasons as yet unknown, those two functions are quite dissimilar. Perception may compensate for one or the other, or perhaps a compromise between them (some sort of weighted mean), but it cannot be a mirror image of both.

In comparison to the above results, those of the French listeners are more confusing. Where the /i-y/ boundary is concerned (see Figure 12, p. 148, above), there is very strong subject-to-subject uniformity in showing high values for isolated vowel, medial values for /dV/, and low values for /bV/ environments. For the /y-u/ boundary, on the other hand, there is little consistency from subject to subject: one shows virtually no boundary shift for environment, three show the expected pattern of higher values for /dV/ context than for /bV/, and five show the reverse.[117]

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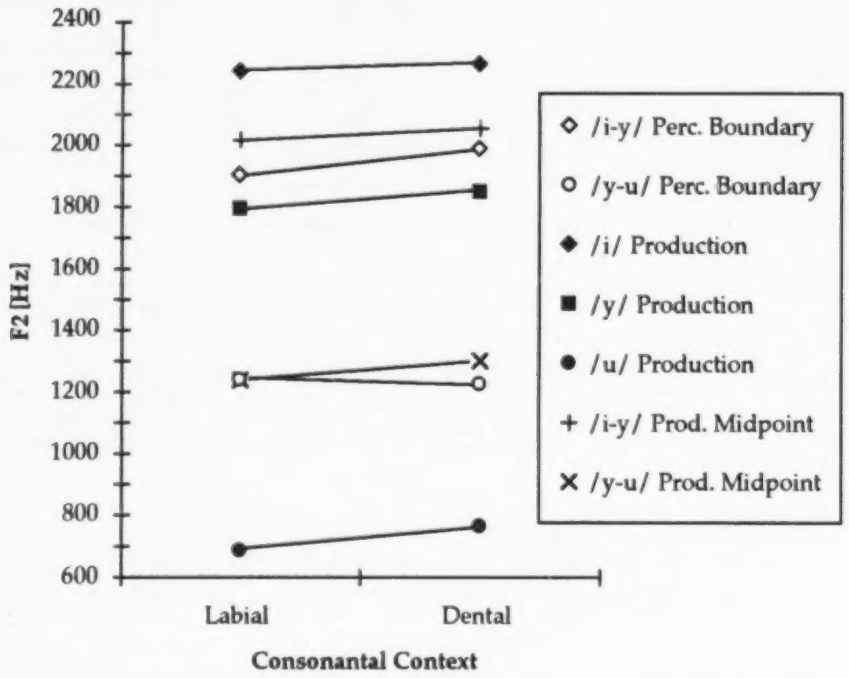
117 This is not the only investigation to find the phenomenon of perceptual undershoot—van Son (1993a, 1993b) has reported it for Dutch vowel perception. For analogous findings with respect to production and perception of VOT in English and French, see

The relationships between production and perception of French /i/, /y/ and /u/ in labial and dental environments pooled across subjects are plotted in Figure 17.

Figure 17: French boundary values for all listeners and F2 production means for /i/, /y/, /u/ and the /i-y/ and /y-u/ production midpoints (means) for male speakers.



In view of the fact that the perceptual functions shown on this plot do not appear to parallel any of the corresponding production functions, a repeated measures analysis was done for each appropriate comparison. These contained Context (/bV/ and /dV/) as the single within-subject factor

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Nearey and Rochet (1994). All three of these studies note significant patterns in perception which work *against* those of production.

and Type of Data (Production and Perception) as the between-subject factor. Here again, it is not the main effects that are of interest, but the interaction of Data Type and Context. For four tests, a Bonferroni adjustment yields an α-level of .0125 for each test. Results of these analyses are given in Table 13.

TABLE 13: Interactive effects of Data Type (perception and production) and Context (labial and dental) in French /i/, /y/ and /u/ ($\alpha = .05/4 = .0125$).

Vowel in Production		Perceptual Boundary	F	p
/i/	vs.	/i-y/	1.684	= .2188
/y/	vs.	/i-y/	0.683	= .4247
/y/	vs.	/y-u/	1.484	= .2465
/u/	vs.	/y-u/	6.362	= .0268

None of these comparisons showed a significant difference. Thus, even the most striking contrast shown in Figure 17, the opposing tendencies of the labial-to-dental functions for production of /u/ and the perceptual distinction of /y/ and /u/, falls short of reaching significance. Future studies, observing greater numbers of subjects, will have to establish whether or not French perception in this respect is truly at cross-purposes with production. Even if such findings should be forthcoming, however, the present data lead one to doubt that the magnitude of those differences would be great. For the moment, the tentative conclusion would seem to be that the effects of the dental-vs.-labial environments on the French high vowels are

minimal in both perception *and* production. From that point of view, it might be said that these perceptual patterns do provide a rather accurate reflection of the corresponding patterns in production.

The final issue which must be discussed in this section is the finding that, in opposition to Hypothesis 3, the French /i-y/ and /y-u/ boundaries did not shift less as a function of environment than the English /i-u/ boundary. What was expected in the formulation of Hypothesis 3 was that differential boundary adjustments for labial as opposed to dental/alveolar environments would be smaller in French than in English. The four pairwise comparisons at issue here (the /dV/-vs.-/bV/ comparisons for each of the two boundary pairings) showed no significant difference between French and English. In light of the small perceptual compensation effects found here for English, this outcome is not surprising. What was unexpected was that, in the two comparisons for which significant difference was found, the differences were not in the direction predicted by the hypothesis. A fifth French perceptual pattern observed here (/#i-#y/ vs. /bi-by/) varied *more* as a function of context than the corresponding pattern of English. The final shift (/#y-#u/ vs. /by-bu/) was equal in magnitude to the English counterpart, but in the opposite direction. The surprise, then, lies in the observation that the two French crossovers for vowel in isolation do differ significantly

from those for vowels in *both* /bV/ and /dV/ contexts—higher in the /i-y/ boundary, lower in /y-u/.[118] This seems to suggest that the French listener demands extreme F2 values for /i/ and /u/ alone, and tolerates less extreme values for these vowels in dental *and* labial environments. Seen from a different perspective, the perceptual category for /y/ widens in isolation, shrinks when preceded by /b/ or /d/. Of course, whether this pattern obtains for other peripheral-vs.-medial vowel contrasts (e.g., /e, ø, o/) and for contexts involving other consonants remains to be discovered.

One aspect of the acoustic and perceptual test results remains untreated: that is the comparison of the production patterns of speakers of one language with the perceptual patterns of those of the other. Presentation of that discussion appears in the following section, where it is used to provide an explanation for the trends observed in the perception of naturally-spoken English vowels by French listeners. For the moment, some comments of a general nature can be used to bring this section to a close.

It is clear that the findings presented here do not give the final word on coarticulatory patterns in the perception of the high vowels in English and

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118 As is shown in the analysis of French boundaries alone (pp. 147-151, above), for the /i-y/ boundary, the isolated vowel environment contrasts significantly with both consonantal contexts. For the /y-u/ boundary, isolated vowel is significantly different from labial environment; the contrast with the dental shows a trend in the same direction, but fails to reach significance.

French and on their relationships with production. First, it must be pointed out that experimental procedure in perceptual testing can affect outcomes. With respect to this, Nearey (1989) obtained somewhat larger effects when tests were administered in "mixed condition" (stimuli from all contexts presented in random order within a single test) than in "blocked condition" (each test containing stimuli within a single environment). The testing for the present investigation was done in blocked condition, and may thus have underestimated the degree of perceptual compensation which listeners actually make in their categorizations.

Secondly, in order to understand in depth the nature of contextual effects in perception, it will be necessary first to know precisely what acoustic cues across the duration of a vocalic signal are used in making categorization decisions. In this regard, Van Son's (1993b: 56) comment bears repetition:

> The quality of synthetic signals as a model of *natural* speech depends on our current knowledge of natural speech. Because we do not know the cues listeners use to identify vowels, such cues might be improperly represented in synthetic signals."

In a similar vein, but with specific reference to cross-linguistic studies, Nearey and Rochet (1994: 16) suggest the following as a possible explanation for unexpected results: "... other properties of the synthesis parameters that were not systematically varied might have had differential effects in the two

languages that obscure effects of the factors investigated here." Whether results are expected or not, the importance of their point must be given heed. In the present study, while it is likely that the parameters manipulated in the synthetic signals are not independent of those which are used by French and English listeners, it is not certain by any means that they are precisely those which have central perceptual salience. In that light, conclusions drawn below are to be taken as tentative.

With the above note of caution borne in mind, three generalizations can be made concerning the differential effects of labial vs. alveolar/dental environments on perception and production of the English and French high vowels, and on the implications of those patterns for the task of French phonetic learning faced by the English speaker.

- With regard to the production of English /i/ and of French /i/ and /y/, contextual effects in the two languages are quite consistent, quite similar, and quite small. For the English-speaking learner of French (or, indeed, for the French-speaking learner of English) it is highly unlikely that any considerable phonetic difficulty will have its source in differences here.
- In line with the above, perceptual compensation for contextual effects, in the French /i-y/ and /y-u/ boundaries as well as in the English /i-u/ boundary, is similarly small; while English learners do have a substantial

perceptual learning task to accomplish—they must learn to distinguish three vowels in the space where they normally hear two—that task does not involve mastering new patterns of perceptual compensation. The only English-French difference in perception found in the present results lies in the shift of the French boundaries for isolated-vowel condition in comparison to consonantal environment—towards higher F2 values for the /i-y/ boundary, towards lower values for /y-u/. This finding is interesting, and clearly merits attention in future research, however, once again, the shift is of small enough magnitude that, at first glance, at least, it would not appear to be a salient source of phonetic difficulty.

- English and French are similar as well in that both show large contextual effects only for the production of the vowel /u/. In contrast to the above cases, however, this similarity does not ease the task of phonetic learning. For even though the magnitude of this shift in French is on the order of twice that of the shifts for the vowels /y/ and /i/ (and of English /i/), it still has only about one third of the size of the corresponding shift in English /u/. Thus, the importance for the learner here is not the similarity to the English pattern, but the difference. If the learner applies the English phonetic realization rule for /u/ in alveolar environment in

producing French /u/, the result will be a highly accented pronunciation and even, as will be seen below, a potential source of misunderstanding.

PERCEPTION OF ENGLISH VOWELS BY FRENCH LISTENERS

In this facet of the study, 14 French listeners identified 7 tokens of each of the words /bub/, /dud/, and /gug/, and 2 each of /bib/, /did/, and /gig/ as produced by each of 10 English-speaking subjects. Thus, each listener heard a total of 210 /u/s and 60 /i/s. Of the total of 840 /i/s heard by all listeners, 839 were identified as French /i/. The single exception, a response of /u/, was judged to be a mistake. These results can be taken as confirmation of Hypothesis 4, above, which predicted that English /i/ would be identified by French listeners as /i/ regardless of consonantal context.

For the presentation of the results concerning French perception of English /u/, the data from four listeners have been excluded. One of these, Fr04, was unique in that he identified no English vowels as /y/. At the end of the test, he noted this fact to the experimenter and stated that, if he had focused on the first portion of the vowel rather than on the last, he would have given many /y/ responses.[119] This comment, taken together with the

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[119] Fr04 added here that he would have given an especially high number of /y/ responses for words containing /d/s. As is shown below, his reaction to the vowel of English

results of the other listeners, suggests that Fr04's approach to vowel identification was more analytic than spontaneous. A second listener whose data have been excluded, Fr07, heard nine tokens of /dud/ as containing the vowel /y/, and 14 as containing /i/. Since no /i/s were chosen in the velar or labial environments, these responses cannot be treated as mistakes. It was judged that this response pattern indicated an abnormally narrow phonetic category for /y/, which could mask any trends which might be noticed.[120] Of the 2520 remaining responses for English /u/, four additional /i/ identifications were made, all for /dud/ tokens. These were treated as /y/ responses in the analysis.

The exclusion of the two remaining subjects is considered in light of observations to be made from Figure 18, which shows the mean proportions of /y/ categorizations of each French listener for all tokens of English /u/ in three consonantal environments. That plot illustrates a rather clear tendency among French listeners to hear more /y/s in tokens of /dud/ than in tokens of /bub/ and /gug/. A striking reversal of that trend is shown by two listeners, Fr12 and Fr10. One might suppose that this is to be accounted for

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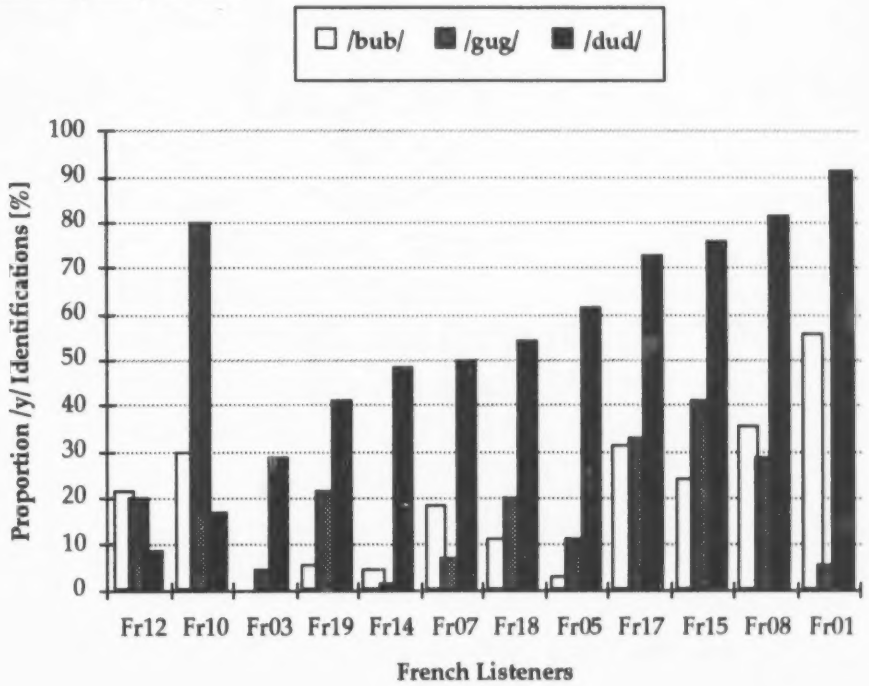
/dud/ is directly in line with that of the subjects whose data were retained for the analysis.

120 It is unfortunate that this subject did not also complete the perceptual test on synthetic signals; data from that may have provided the opportunity to confirm or reject this interpretation.

by a different reaction to the glides present in the English signals. Whatever may be the final explanation, it was felt that this divergence from the norm might compromise the clarity of results; in the following, therefore, the data from these two listeners have also been excluded from the corpus.[121]

Figure 18: Mean proportions of /y/ identifications given by French listeners for English /u/ in three consonantal environments. Ordering is according to increasing proportions of /y/ responses to /dud/ stimuli.



The mean proportions of /y/ responses for each consonantal context within each listener were submitted to a repeated measures analysis. This

121 If the data from subjects Fr10 and Fr12 are included in the analysis, there is a rise in the probability levels for the main effect of context and for the comparisons of means (see following page), however, decisions concerning the acceptance or rejection of null hypotheses are not altered.

showed the main effect of context to be highly significant [F (2, 18) = 45.924; $p < .0001$]. More important for the present interests are the contrasts of means under this effect. The means and standard deviations for each environment are given in Table 14.

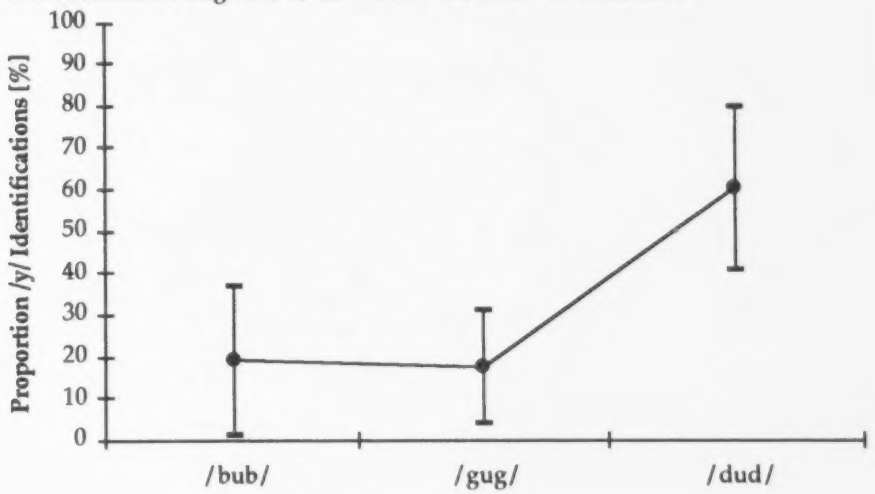
TABLE 14: Mean percentages and standard deviations of /y/ identifications given by French listeners to stimuli containing English /u/ in three consonantal environments.

	Mean	St. Dev.
/bub/	19	18
/gug/	17	14
/dud/	61	19

F-ratios for comparisons of means (df = 1, 18) showed significant differences between the contexts /dVd/ and /bVb/ [$F = 66.069$; $p < .0001$], and between /dVd/ and /gVg/ [$F = 71.593$; $p < .0001$]. No significant difference was found between /bVb/ and /gVg/ [$F = 0.111$; $p = .7430$]. Figure 19 plots these contextual means and standard deviations. Standing in contrast to the clear trend to hear more /y/s in the alveolar environment is the lack of consistent perceptual treatment accorded to labial and velar environments. This is illustrated most clearly in Figure 18, above, which shows that half of the

listeners heard more /y/s in tokens of /bub/, while the other half heard more in those of /gug/.[122]

Figure 19: Mean percentages and 1-standard-deviation error bars of /y/ identifications given by French listeners for English /u/ in three consonantal environments.



Hypothesis 5 predicted that French listeners would hear English /u/ as either /u/ or /y/, more often as /u/ in labial and velar contexts, more often as /y/ in alveolar. That prediction is borne out by these results. Across the three consonantal contexts, these listeners identified roughly 1 of 3 English /u/s as /y/. In /bVb/ and /gVg/ environments, 1 of 5 English /u/s was categorized as /y/, while in /dVd/ context, that proportion rises to 3 of 5.

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122 This ambivalent nature of the velar context has been observed as well in production patterns of French speakers (p. 134, above). A search for within-subject correlation between production and perception in this regard would be an interesting study.

DISCUSSION

The central thesis underlying this portion of the present study is that French patterns of vowel perception along the F2 scale would show less shift as a function of consonantal context than would English patterns of vowel production, and that, as a consequence of those differential treatments of environments, French listeners would identify a higher proportion of /y/s in tokens of English /dud/ than in tokens of /bub/ and /dud/. The two predictions have found support in the results. There remains yet the issue of the association of the second prediction with the first—that is, whether there is any correlational link between the F2 measurements taken for the test stimuli and the proportion of /y/ identifications they were given.

To investigate this issue a Partial (Type III) Sums of Squares analysis was performed on the data,[123] with the number of /y/ identifications per token as the dependent variable, and with the following three factors:

1. **F2**: the F2 measurement taken for that token, either from the peak, or from the halfway point in the signal, as described above;

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123 The assistance of T. Nearey in conducting this analysis (as well as in interpreting the results) is gratefully acknowledged.

2. **Context**: /bVb/, /gVg/, /dVd/—presumably, some acoustic properties particular to each consonantal environment which were important for listeners, but which were not measured;
3. **Speaker**: the English speaker who provided the token—representing, perhaps, perceptual compensation shifts made by the listeners on the basis of their judgements about the individual speakers (sex, size, etc.)—e.g., conclusions about what filter resonances (F1, F2, ...) should be like in light of perceived frequencies in the source (F0).

This analysis revealed highly significant effects, at or beyond the .0001 probability level, for each of those three factors: F2 [F (1, 197) = 52.846]; Context [F (2, 197) = 79.407]; Speaker [F (9, 197) = 5.244]. Thus, while the F2 measurements taken for these test items do not come close to predicting all of the variance in the French listeners' categorizations, they do predict a meaningful part of it; this can be taken as an indication that, while the values recorded are not the precise acoustic cues used by French listeners in making their perceptual judgements, neither are they independent of those cues.

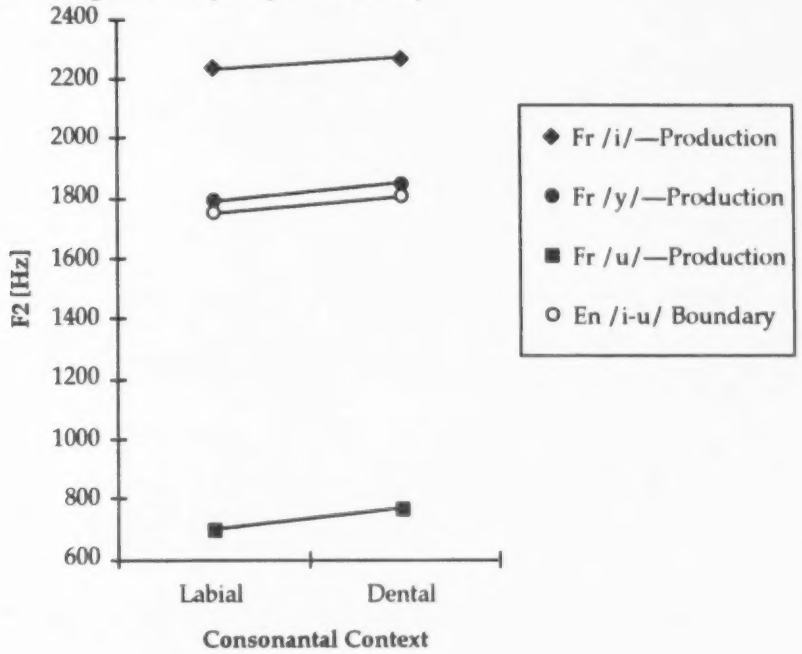
Among the objectives of the present study (outlined in the preceding chapter), only those of offering linguistic *description* have been addressed thus far at any length. That is, vowel production has been compared to vowel perception for both English and French. Cross-linguistic comparisons have

been made for both production and perception in English and French. However, the fundamental motivating goal of the investigation was to provide *explanation* of phonetic difficulty, and that with an eye to application in the teaching of French pronunciation to English-speaking learners; this central topic is addressed below. A hoped-for ancillary outcome was to offer an explanation of the complete process of interlingual identification in second-language phonetic learning. That is, it was intended to use as a starting point the work of Rochet (1995) in accounting for the fact that English learners equate French /i/ with their English /i/ and treat both French /y/ and /u/ as members of their English /u/ category, and then to extend it by incorporating the added dimension of contextual variation. That this issue has not yet been broached is explained in a comment made by Rochet in that paper:

> Although [the] comparison of the labeling functions by the three groups of subjects is of interest inasmuch as it reveals how these subjects *perceive* and categorize the high vowel continuum in their respective languages, it must be kept in mind that to give an adequate account of interlingual identification, we must not relate the L2 learners' L1 identification functions to those of the native speakers of the target language, but to the characteristics of those speakers' *productions*. For example, when called upon to imitate French /y/, L2 learners do not have access to French categorization functions, but only to natural tokens of that vowel pronounced by native French speakers. It is, therefore, necessary to juxtapose the L2 learners' identification functions with the mean (prototypic) F2 values of the vowel /y/ obtained from production data in the target language. (pp. 377-379)

The comparisons of interest, then, are those involving perceptual patterns in one language and production patterns in the other. In the first step of the interlingual identification process, the concern is with the relationship of production in L2 (French in this instance) to perception in L1 (English). Figure 20 plots these functions.[124]

Figure 20: French F2 production means for the vowels /i/, /y/, and /u/ by male speakers and the mean English /i-u/ perceptual boundary.



The reader will recall that the effect of Context for English perception of /i/ and /u/ was found to be significant, but that the boundary shift associated with that effect was quite small (57 Hz). There was no significant

124 Once again, since the perceptual boundary values for this study were established on the basis of synthesized signals appropriate for a male speaker, only values from male speakers are used to calculate the production means.

effect of context in the production of French /i/ and /y/. The only production effect plotted in Figure 20 for which significance was found, then, is the labial-dental contrast for French /u/—and that effect, while considerable, was not large (129 Hz). Given the fact that French /i/ and /u/ are so distant from the English perceptual boundary, contextual effects alter nothing in the categorization of those vowels by English listeners.

The perplexing revelation of this graph concerns not effects due to environment, but the overall placement of the English boundary—at 1749 and 1806 Hz for labial and dental environments, respectively—just below the production mean for French /y/. With these values, one would expect a split in English categorizations of French /y/—that English listeners would hear more than half of them as /i/, some fewer than half as /u/. Yet as Rochet (1995) notes in his paper, English learners consistently return an [u]-like vowel in the attempt to imitate French /y/, suggesting that that is how they perceive it. The male-speaker production mean found here across the three environments is 1821 Hz, slightly lower than the 1850-Hz value given by Delattre (1948), but quite high in comparison to the 1675-Hz specification given by O'Shaughnessy (1982) as well as to the mean of 1760 Hz found by

Rochet.[125] Thus, it appears that the F2 values found here for French /y/ tend toward the high end of the range. If that is so, it is no doubt due to the fact that the group of French speakers for the present study included only two males. Yet even using Rochet's production values in place of these, one would expect to find a non-negligible number of /i/ identifications coming from English listeners, for the English boundary values found here also diverge from previous findings; the present means are approximately 100 and 150 Hz lower than the value reported by Rochet, depending on consonantal context. The end product of this is that the present results do not succeed very well in accounting for the fact that English speakers consistently render French /y/ as some kind of [u] (Rochet, 1995)—in short, do not succeed in accounting for the first step of the process of interlingual identification. These divergences from the findings of Rochet remain an enigma, given that his results were produced by signals and procedures very similar to those used here.[126] Still, that issue aside, it may well be that English listeners use other cues present in natural tokens of French /y/ which were not manipulated in these synthetic signals.

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125 Rochet (1995: 379) reported a range of 1612 to 1824 Hz for his group of 10 native speakers of Standard French.

126 As is discussed below, the French crossover values found here are much closer to those found by Rochet (1995) for his French listeners. This indicates that the synthetic signals were treated more similarly by the groups of French subjects in the two investigations than by the English groups.

The process of producing an L2 sound involves two broad steps. In the first, that discussed immediately above, the L2 learner categorizes L2 sounds as members of existing L1 categories. The second broad step, the one of central interest here, involves the production of L2 sounds via existing L1 phonetic realization rules; it is here that, given an understanding of how L2 sounds are categorized by learners, one should find the explanation for phonetic difficulty. It is here as well that one should find the explanation for the varying proportions of /y/ identifications given to naturally-produced English words by French listeners. These explanations require the converse comparison to the one above—that is, the degree of divergence of learners' pronunciations from L2 norms must be assessed on the basis of a comparison of L1 patterns of production and L2 perceptual expectations.

Figure 21 plots these functions. The mean F2 value found here for the French /i-y/ boundary is 2054 Hz for vowel in isolation; this value appears to be nearly identical to Rochet's (1995) finding.[127] It will be recalled that the only significant contextual contrasts for this boundary were those between isolated vowel and consonantal environment; both /bV/ and /dV/ boundaries were lower (with values of 1961 and 1988 Hz respectively), but

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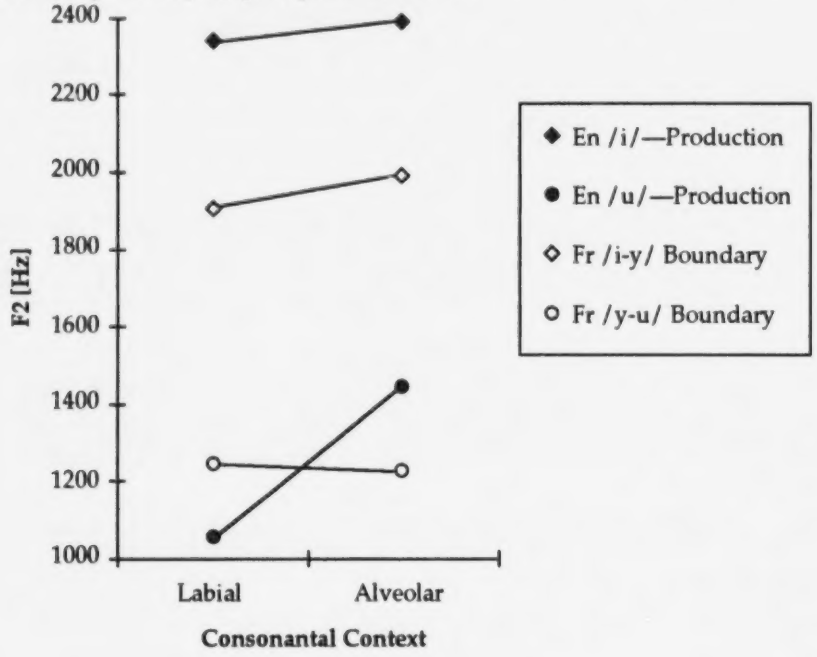
127 Rochet does not report a precise value, but it is clear from his Figure 4 that the boundary value would be close to 2050 Hz if the same computational formulas were used.

did not differ significantly from each other. At any rate, the shifts in the English production of /i/ and in this French perceptual boundary are very small compared to the rather great acoustic distance between these two functions in Figure 21. This distance accounts for the fact that all exemplars of English /i/, regardless of context, were identified as /i/ by French listeners.

Figure 21: English F2 production means for the vowels /i/ and /u/ by male speakers and the mean French /i-y/ and /y-u/ perceptual boundaries.



Concerning the French /y-u/ boundary, recall that no significant difference was found for the /bV/-/dV/ contrast; once again, the real difference was between isolated vowel and consonantal environment (though the /#V/-/dV/ comparison missed significance rather narrowly). Compared

to the proportions of any of these shifts in French perception, that seen for production of English /u/ is large indeed. This explains the fact that, between labials, English /u/ has a low enough F2 to lead French listeners to identify most tokens as /u/ (roughly 4 of 5 in our results). On the other hand as is indicated by the intersection of the functions for production of English /u/ and the French /y-u/ perceptual boundary, in alveolar environment, the mean F2 of English /u/ is raised enough to place it well within the boundary of French /y/, thus accounting for the categorization of a majority (3 of 5) of the English /u/s in this study as French /y/.

It has been noted above, in the discussion dealing with the acoustic analysis of the English and French high vowels, that English /u/ cannot be equated with either French /u/ or /y/, but rather that it falls midway between the two. But its position between those two French sounds shifts as a function of its environment, tending more towards /u/ in labial and velar contexts, more towards /y/ in alveolar contexts. Still, interesting as that finding is, and important as it is to know, the proof of phonetic difficulty lies in the comparison of what learners say with what L2 listeners hear. The results given by the French listeners in this study confirm that, for English-speaking learners, the relative difficulty of French /y/ and /u/ is not constant, but changes as a function of the consonants which surround it.

CONCLUSIONS

THE PHONETIC DIFFICULTY OF FRENCH /y/ AND /u/

It has been pointed out (pp. 99-100, above) that the commonly-expressed conception of French /y/ and /u/ in pedagogical materials has it that the former is a difficult sound for English-speaking learners to master, because their L1 inventory has no such vowel. The accompanying unexpressed assumption is that the latter vowel is less difficult, because English also has an /u/. These claims fail to find support in contrasts based on phonetic substance. Equally unsupported is the converse claim (Flege, 1987) that the "similar" French /u/ is more difficult than the "new" French /y/ for English speakers. The acoustic shape of the realizations of English /u/ changes as its phonetic/phonological surroundings change, to the point that, in alveolar environment, a majority of English /u/s are heard by French listeners as members of their /y/ category. (Moreover, even in the labial environment, which tends most to foster low F2s, those values remain high enough for French listeners to identify a non-negligible portion of these /u/s as /y/.)

Therefore, any generalization concerning the relative difficulty of French /y/ and /u/ which is not context-sensitive is an erroneous one.

As Rochet (1994: 179) has noted, both French /y/ and /u/ are difficult sounds for English-speaking learners. This is so because neither of these target vowels is very much like the English /u/, with which they are perceptually equated; rather, acoustically, they surround that L1 vowel. And each of these two French vowels is more difficult in some contexts than in others, for difficulty is a product not only of phonetic distance between L1 and L2 production norms, but also—and especially—of distance between L1 production norms and the perceptual expectations of L2 listeners. When English-speaking learners use English /u/ in their L2 speech, it is heard as either /y/ or /u/ by French listeners, depending—largely, but not entirely—on its consonantal context. Real misunderstanding can be the consequence of this substitution: the minimal-pair antonyms *dessus* [dəsy] and *dessous* [dəsu] are a case in point. Admittedly, such cases are few in number, Still, even when the possibility of misunderstanding is precluded by part-of-speech differences and/or semantic context, the problem is serious. When a learner is heard to say *On a bu tout le vin* with /bu/ and /ty/ instead of /by/ and /tu/, there can be no doubt about the content of the intended message, but

the distance between the perceived and expected shapes of the two high vowels is sufficient to give the impression of a very strong foreign accent.

There is a more accurate generalization to take the place of those oversimplifications noted above—one which practitioners will more likely find to correspond to the reality which they observe in their day-to-day work. Other vowel problems aside (those which apply to all vowels—i.e., reduction, diphthongization, and the like), both French /y/ and /u/ are difficult sounds for English-speaking learners: /y/ especially so in labial and velar environments, /u/ in dental environment.

THE OPTIMAL PERCEPTUAL ENVIRONMENT

The brief review of the Verbo-Tonal approach to L2 phonetic correction (pp. 93-96, above) notes that central to this method is the principle that improvement in pronunciation is to be effected through the development of accurate perception. Progress in this latter domain, in turn, is to be the product of the learners' listening to target sounds exclusively in their "optimal environment". Literature reviewed and empirical results obtained in the present study provide tools for a critical evaluation of some of the methods espoused in this approach. The central principle undergirding the

Verbo-Tonal approach is that speech sounds influence each other (Landercy and Renard, 1976: 177), however, the precise reasoning which leads from that principle to the notion of optimal environment is not described. It is necessary, then, to address this notion from three points of view.

One assumption on which the optimal environment may rest is that a given vowel has a perceptibly different shape in some surroundings than in others. Unlike Delattre's (1951) modes, which are clearly formulated to prescribe an approach for English-speaking learners of French, the Verbo-Tonal method seems to be presented as a universally-applicable one, appropriate for learners of any L2 and coming from any L1 background (though the vast majority of the language-specific references contained in the writings speak of French as the L2 and English as the L1). This sweeping generalization is surprising, since it assumes that all sounds in all languages influence each other in similar ways; however, it is this writer's judgement that the assumption must be shown to hold true for the particular languages for which the method is to be applied. For the present purposes, of course, the accuracy of that assumption will be considered as it relates to the learning of French by native speakers of English.

This first issue, then, involves the contextually-induced variability in the production of French vowels as it relates to the corresponding variability in

the perception of English listeners. The results obtained in this investigation suggest that there is no significant contextual variability in the production of French /i/ and /y/. Consequently, there appears to be no empirical basis for the claim that one of these three environments is better than another for these vowels. The largest contextual effect observed for French production was the labial-vs.-dental contrast for the vowel /u/; here the F2 mean difference was 129 Hz. However, it must be recalled that a compensatory shift of 57 Hz was observed in the perception of English listeners. When one computes the difference, then, it becomes clear that the *effective* labial-to-dental difference is of little magnitude, and unlikely to be important in fostering improvement in the pronunciation of that vowel.[128]

Another claim concerning this notion, it will be recalled, is that an optimal environment is one in which the targeted sound most closely "resembles" its surroundings—i.e., the type of condition which produces the flattest V-to-C and C-to-V transitions. Landercy and Renard (1976: 187) give

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128 The data from the French production of /u/ and the English /i-u/ perceptual boundary were submitted to a repeated-measures analysis with Type of Data (French Production and English Perception) as the between-subject factor and Context (Labial and Dental) as the within-subject factor. The effect of the Data Type-by-Context interaction narrowly missed significance [$F(1, 19) = 4.079$; $p = .0578$]; there is therefore no statistical reason for drawing a different conclusion. Nonetheless, in light of that slim margin, it may well be that some future investigation may find a significant difference. Even if that were to occur, however, it is judged here that the difference involved is not large enough to be important in application.

as the reason for preferring this kind of context the claim that it demands the smallest expenditure of "perceptual effort". Earlier in the same article, after presenting a listing of the effects which groups of sounds exert upon other sounds, they offer the following:

> On imagine aisément le profit que le pédagogue peut retirer de la connaissance qu'il a de ces effets. On mettra plus aisément en relief le caractère sombre (ou clair) du timbre d'une voyelle en l'associant à une consonne relativement grave (ou aiguë): on éduquera mieux l'audition d'un anglophone ou d'un hispanophone produisant [u] au lieu de [y] en lui présentant ce son dans des mots tels que *suce, tu, chute,* plutôt que dans *murmure* ou *jupe*; ... (p. 178)

The choice of the expression *mettre en relief* here gives a surprising analogy, for it creates an unexpected irony in this passage. The juxtaposition of sounds which share acoustic attributes and which, therefore, produce flat transitions, does not create relief; rather it obscures distinctions, *levels* relief. Upon encountering such a claim, one is inevitably reminded of one of the central principles of the perceptual fading technique adopted by Jamieson and Morosan (1986): that of beginning perceptual training by contrasting *maximally differentiated* stimuli. The success of that technique in fostering phonetic learning is due, in large part, no doubt, to the fact that stark contrasts demand not more, but less perceptual effort than fine distinctions.

A final issue surrounding the notion of the optimal perceptual environment involves the likelihood of its finding success in application.

Powerful demands are placed on the practice of presenting sounds *only* in their optimal contexts—i.e., this approach is based on the assumption that practice in hearing a given sound in its optimal environment will indeed foster accurate perception *and* production of that sound in that context and, moreover, that there will be transfer of these improvements to perception and production of the same sound in less ideal environments. Of course, in the end, this is a claim which demands empirical proof. If such empirical support has been found, it has escaped the attention of this writer. Furthermore, it is judged here that such support is unlikely to be found. One might consider, for example, the case of an English-speaking learner of French who is heard to pronounce /u/ in *doux* with excessive fronting. Corrective measures would perhaps consist of having that learner listen to repetitions of *bout*. If there is any basis in reality for the notion of equivalence classification, which holds that learners identify L2 sounds as members of L1 categories and subsequently utter those sounds according to L1 realization rules, such corrective measures are not likely to be fruitful. It would seem far more reasonable to try to correct the error by focusing on the environment in which it occurs rather than on one in which it does not occur.

Involved in the whole Verbo-Tonal approach to corrective phonetics are other issues which demand to be addressed, but which lie beyond the scope

of this study.[129] Nevertheless, the concept of optimal perceptual environment places itself at the centre of the method. In light of the points raised in this discussion, it is difficult to reach any conclusion other than that the notion is not well-founded. It becomes difficult to place much faith in the approach.

THE OPTIMAL PRODUCTION ENVIRONMENT

Valdman's (1993) application of the optimal environment differs from that in the Verbo-Tonal approach in that it pertains to production rather than perception of L2 sounds. Its role is less central to the overall method in that it serves merely to specify the ordering of tokens within practice exercises; no context-to-context carryover is assumed, since learners do practice sounds in all environments. From that point of view, empirical support for the procedure is somewhat less crucial than in the case of the Verbo-Tonal method; the concern is whether the approach can be expected to facilitate learning, rather than whether it does a disservice to learners in withholding important aspects of training from them.

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129 The most notable of these other issues is the claim that this phonetic learning can occur—and the prescription that it *should* occur—without the conscious attention of the learner being directed to accuracy of pronunciation, for that might compromise spontaneity of expression (Landercy and Renard, 1976: 174). One wonders what thoughts must go through the mind of the student who is asked to listen to repetitions of *bout* or *dis* without really knowing why.

The assumption on which this notion is based is that coarticulatory effects of consonants on vowels are greater in English than in French—greater especially in English production than in French perception. Where French /i/ is concerned, it is recalled that Valdman presents a list of words which give increasing difficulty to learners as they try to pronounce them with an acceptably "strong tension" (involving, presumably, adequately low F1 and high F2). With respect to F2 values, the results obtained in the present study do not offer support for the method. The acoustic analysis showed no significant effect either of language or of the language-by-context interaction. In fact, the F2 means for English /i/ were non-significantly higher than those for French /i/ in all environments.[130] Of course, the present results have nothing to say concerning F1 values, however, in light of previous findings of little effect of consonantal context on that formant (Stevens and House, 1963), it seems unlikely that the facilitating-environments approach will facilitate very much.

In contrast to the above, it has been shown that the production of French /y/ and /u/ by English-speaking learners, both of which are equated with

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130 It is true that the F2 means found here for English /i/ were high in comparison to those found by Stevens and House (1963) and Ohde and Sharf (1975); this may be due to dialectal differences. Still, if one compares the results from those two studies with the means found here for French subjects, it appears that the English /i/s produced by their speakers should be quite acceptable to French listeners as well, at least along the F2 dimension.

their L1 /u/, are likely to be strongly affected by consonantal environment. Learners' realizations of /y/ can be expected to show unacceptably low F2 values especially in labial and velar contexts; those of their /u/s can be expected to be much too high in dental context. There remains, of course, the question of whether or not these errors have their source in articulatory difficulty, and, therefore, whether or not a less-difficult-to-more-difficult progression in pronunciation exercises might be helpful. That issue is treated below. For the moment, let it suffice to say that, insofar as errors in pronunciation of French /y/ and /u/ are due to difficulty of articulation, Valdman's application of optimal environments for these vowels is well-founded.

THE SHAPE OF THE CURRICULUM FOR THE FRENCH HIGH VOWELS

The end goal of a study such as this is that it provide a recommendation or series of recommendations for application. In that interest, this section attempts to delineate an approach to the teaching of the French high vowels to English-speaking learners. The reader is asked to bear in mind in considering this plan that, while this study has answered a few questions, it has left many unanswered. Accordingly, although some of the following

recommendations are based on some fairly solid knowledge, others rest necessarily on intuition—teaching and learning must happen, even if there remain substantial gaps in our understanding.

Results from this investigation suggest that French /i/ does not create great difficulty for speakers of Canadian English. The reader is reminded of Valdman's (1993: 45) remark concerning the difficulty of maintaining adequately "strong tension" in the pronunciation of this vowel in certain environments. As is noted above, the present results do not support that observation as it pertains to values of F2. Furthermore, as the author listened to the tokens of English /i/ recorded for this study, it seemed to him that vowel height was also well in line with French norms. Finally, this notion of tension is often associated with spectral stability or lack of diphthongization (Delattre, 1951); however, here as well, the author's ear and the spectrograms of these tokens indicated that glides constituted a much less serious problem for this vowel than for /u/. The judgement here is that the only situation in which learners will be likely to miss the French /i/ target by a large margin will be when it is unstressed. That problem, of course, is a particularly troublesome one pertaining to all vowels, and must be dealt with elsewhere in the curriculum. All this is not to be construed as a criticism of Valdman's remark—his experience is with a different set of learners. The point to be

taken is that, for speakers of *Canadian* English, French /i/ need not be given special consideration.

One cannot say the same with regard to French /y/ and /u/. The question of import, then, concerns the source of the substantial difficulty that these sounds pose to learners. All indications at this point lead to the conclusion that the source is *perceptual*. Rochet's (1995) study found that 51% of the attempts by English speakers to pronounce French /y/ were judged by French listeners to have been successful. The present results show that, across contexts, 1 of 3 English /u/s is identified as /y/ by French listeners, 2 of 3 as /u/. English speakers *can* articulate acceptable tokens of both sounds; the problem is that, in their French speech, they often *do* not articulate them in the appropriate places.[131] If that is so, it seems reasonable to believe that it is the result of the process of equivalence classification at work—that is, not hearing a functional difference between the two sounds, they have no reason deliberately to produce two different sounds. In any given utterance, then, the phonetic actualization—/u/ or /y/—is the product, primarily, of contextually-determined variability, but also of token-to-token variability. If

131 It is the author's observation, year-in and year-out, that beginning students on the second day of class produce very acceptable tokens of both these vowels; however, throughout the year, when the task involves something other than mimicry, they persistently substitute one for the other. As noted by Ladefoged (1967: 169), "if people can hear a difference between a pair of similar sounds, then they *can* make the difference—but do not necessarily do so in their ordinary speech."

learners know the importance of producing a functional difference, they will make it. And the way to teach them that the distinction is important—merely telling them so is ineffectual—is to lead them to *hear* the difference.

The preceding discussion leads to the conclusion that perceptual training must constitute a central part of the approach to the teaching of the /y/-/u/ distinction. Prototype training (Jamieson and Morosan, 1989) is an essential minimum; future research must determine whether the perceptual fading technique can yield better results with respect to this contrast. Since one of the primary objectives of the course in pronunciation is that learners develop the ability to monitor their own speech effectively, practice should include distinguishing between L1 and L2 vowels. Finally, in order to stress the importance of the /y/-/u/ distinction, the process should include exercises in which learners are asked to make semantic interpretations on the basis of phonetic distinctions; for this, one might present one member of a minimal pair in an unbiased context and ask learners to identify what they hear: e.g., *Prenez cette (roue/rue)-là.*

The assessment that the phonetic difficulty associated with these two vowels has its source in perception does not preclude the incorporation of articulatory description into the pedagogical approach. Such description can

be provided with a minimal expenditure of time,[132] and it is recommended that it be included in the curriculum; in doing so, one offers an additional tool which learners can put to use in their attempts to master this contrast, a buttress for the perceptual distinction they must develop.

Pronunciation exercises continue to constitute an important component of this part of the curriculum. The motivation for this is two-fold—and the first objective is to give learners practice in self-monitoring. The desired outcome of learners' formation of new phonetic categories is not only that they improve their understanding of the L2 speech of others, but also that they monitor their own L2 speech, submit it to the proof of their own ears. The second objective is to provide articulatory practice. The claim that the difficulty associated with French /y/ and /u/ is perceptual should not be taken to mean that movements of articulators play no role in learners' errors. Calvé's (1977) paper treating the place of the language laboratory in second-language teaching made the following assertion: "... s'il est faux de prétendre que la langue n'est qu'un système d'habitudes, il serait tout aussi faux de dire qu'elle n'en contient aucune ... ." (p. 512) That the articulation of English /u/

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132 For /y/, one needs merely to ask learners to round and project the lips while maintaining the tongue placement for /i/. By asking them to contrast their own /i/ and /u/, one can sensitize them to the fronting and backing movements of the tongue. If they then exaggerate that backed position and keep the lips well-pursed, they can produce a very acceptable /u/.

is one of those aspects of language in which habit is at work is not difficult to believe. Flege (1995: 3) has referred to phonetic realization rules as "gestural scores". The analogy contained in this term suggests that the neural commands sent to articulators to execute the production of a sound are not issued in isolation, but as a package, an orchestration (Flege also uses the term "motor program"). That is, they order the completion of a cooperative effort by members of a team. The fronting of English /u/ in alveolar context (and its backing in labial context) would appear to be an ideal situation for the formation of articulatory habits having their source in the execution of these orchestrated commands.[133] Pronunciation exercises provide the opportunity to develop control over this propensity of articulators to work in concert with one another, always in the same way.

Pronunciation exercises may well include exemplars containing the targeted vowels in "optimal environments"—indeed, in exercises involving the contrast of /y/ and /u/, that becomes inevitable. However, the focus of attention should be placed upon the contexts which pose the most serious problems: labials and velars for /y/, dentals for /u/. Bound to this, however,

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133 Above, there is reference to a "recipe" for producing French /y/. When beginning learners are asked to pronounce /i/, but with rounded lips, most do it on the first try. A few, in the first attempt, produce a typical English /u/—that is, when the lips round, the tongue moves back. It may take these learners two or three tries to realize a good /y/. The point to be taken from this is that they *can* do it—but they are not *accustomed* to doing it.

is the mandate that learners be made aware of the reason for the high proportion of certain kinds of words in certain exercises (e.g., dental consonants with /u/). They can deal with the problem most effectively if they have a very clear idea of the nature of that problem. This implies, then, that the cognitive component of the curriculum must include a description of the changes effected upon these vowels (in English) as a function of the consonants that surround them. If learners succeed in producing an acceptable /y/ in velar and labial contexts, an acceptable /u/ in the neighbourhood of dentals, they will not do less well for the same vowels in the less problematic environments.[134]

The preceding prescriptions for the teaching of French /i/, /y/ and /u/ are advanced with due modesty and should be considered as tentative; for as pointed out in the introduction to this section, there remain many unanswered questions in the area of applied phonology. Accordingly, in the pedagogy of L2 pronunciation (as in the pedagogy of everything else, no doubt), curriculum design is not a task to be completed and abandoned, but an ongoing process. As we grow in our understanding of phonological

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134 B. Rochet, in personal communication, has indicated that in teaching the French "light *l*", he has abandoned the practice of asking his students to do exercises containing /l/ in word-initial position. If learners focus their attention on the problem areas, and succeed in eradicating their "dark *l*" from the least favourable contexts (e.g., pre-consonantal and word-final positions), their word-initial /l/s will be fine.

systems and of phonological learning, curricula must be modified to reflect that growth. All of that notwithstanding, it is believed that the practices recommended here, if put into effect, will foster real improvement in the teaching of this aspect of pronunciation correction.

SUGGESTIONS FOR FUTURE RESEARCH

The final paragraph of the preceding section leads to the conclusion that the list of questions which yet have no answers is unending. Heading that list is probably the question of precisely what acoustic cues in a vocalic signal listeners heed in making categorization decisions. It is possible that understanding of this type would account for such perplexing findings as the perceptual undershoot observed in some of the subjects who participated in the present study. More importantly, it would provide a yet clearer indication of how contextual effects in the perception of speakers of one language interact with those of listeners of another. Firm answers to this question—especially as they relate to cross-linguistic differences—will be forthcoming only after great expenditure of time and effort. Fortunately, researchers are working on this issue, and tools and techniques are being improved constantly—there is room for optimism.

For the rest, suggestions made here for future research will be limited to a few investigations which have a more limited scope, and which are more closely linked to the present one in goals and in design. The most obvious need is for experiments looking into the coarticulatory effects of other consonants on these same vowels. For example, one wonders about the magnitude of the differential effect of manner of articulation within place. This suggestion leads inevitably to that of research into other vowel contrasts as well. The English-French high-mid vowels, /e, (ø), o/, could be studied with a design similar to the present one, provided that open syllables were maintained.

The least expected finding in the present study concerned the tendency of the French perceptual boundaries to move toward the acoustic periphery for the isolated-vowel context. An interesting follow-up experiment would involve looking at this perceptual trend in more depth, first to see whether the present results can find replication, and secondly to look for correlations with that trend in vowel production. As it stands now, it is impossible to know precisely how to treat in the curriculum the French vowels /i/, /y/ and /u/ in isolation. The limited magnitude of the spectral shifts observed here suggest that this environment is unlikely to require special treatment; however, further empirical support for that assessment would be useful.

Finally, an observation made in the classroom suggests yet another potentially fruitful topic for research. In recent years (perhaps as a result of heightened sensitivity to some of the apparent mystery surrounding English /u/), the author has observed beginning students to produce English /o/ in mimicking French /u/. The incidence of this is not frequent; but then, in most cases, students know how to spell the words which they repeat—that knowledge may well prevent their /o/ realizations in many instances. Such substitutions could conceivably be the result of a high F1 value in the stimulus, but that is judged to be unlikely in these cases. These occurrences suggest the possibility that the perceptual category for English /u/ may have a lower limit along the F2 scale, that below this limit (some?) English listeners may hear /o/ rather than /u/, and, if that were shown to be the case, that English /u/ might be characterized more appropriately as a high central vowel, than as a back vowel. The investigation of this question would require the construction of a synthetic vowel continuum having the form of an F1-F2 matrix.

In the end, there remain two imperatives to be underscored through repetition. They specify the necessary shape of any investigation that is to provide understanding useful for application in the pedagogy of second-language corrective phonetics. The first is that comparison of the linguistic

units of one language with those of another "only becomes feasible via absolute phonetic facts" (Kohler, 1981: 213). The second is merely a logical extension of the first: "... phonological elements can no longer be ambivalent with regard to production and perception ..." (p. 214). The communication of a message involves, within both the speaker and the listener, processes which are not very well understood, because they are very well hidden from view. Between the speaker and the listener is the most-readily observable link in the chain: the output of the speaker, and the input to the listener—the soundwave. Any research project which aims at providing understanding that will be valuable in application is likely to find success only if it accords central attention to that central, observable, phenomenon.

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NOTE: Articles marked with "" were available to the author only as draft copies at the time of this writing. Consequently, page numbers from those studies referred to in the text of this thesis will not match those of the published works. By contrast, the one paper marked with "‡", Rochet (1995), was available in galley proofs; the page numbers cited from this work should be the same as those in the publication when it appears.*

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APPENDIX A

SUBJECTS

Table 15: European French Subjects. Checks (√) indicate participation in a given component of the study: ***Acoustic***—subject's speech samples were used for acoustic analysis; ***Natural***—subject participated as a listener in the Natural Signals Test; ***Synthetic***—subject participated as a listener in the Synthetic Signals Test.

Subject	Sex	Age	Origin	L2*	Acoustic	Natural	Synthetic
Fr01	M	34	South	Spanish		√	
Fr02	M	53	South	English	√		
Fr03	F	27	South	English	√	√	
Fr04	M	21	South	-		√	√
Fr05	M	26	North	English		√	
Fr06	M	21	South	-			√
Fr07	F	12	South	-		√	
Fr08	M	40	South	-		√	√
Fr09	F	27	North	English	√		
Fr10	M	25	South	-		√	
Fr11	M	26	South	English	√		
Fr12	M	75	South	-		√	√
Fr13	M	41	South	-		√	
Fr14	M	63	South	-		√	√
Fr15	F	74	South	-		√	√
Fr16	F	57	North	English	√		
Fr17	M	22	South	-		√	√
Fr18	F	21	South	-		√	√
Fr19	F	21	South	-		√	√

* Subjects for whom a second language is listed are fluent in that language. Other subjects are monolinguals.

Table 16: Canadian English Subjects. Checks (√) indicate participation in a given component of the study: ***Acoustic***—subject's speech samples were used for acoustic analysis; ***Natural***—subject's speech samples were included in the Natural Signals Test administered to French listeners; ***Synthetic***—subject participated as a listener in the Synthetic Signals Test.

Subject	Sex	Age	Origin	Acoustic	Natural	Synthetic
En01*	F	42	East	√	√	√
En02	M	52	West			√
En03	F	51	West	√	√	√†
En04	F	43	East			√†
En05	M	36	West	√	√	
En06	M	32	West			√
En07	M	38	West	√		√
En08	M	23	West			√
En09	F	55	West	√	√	
En10*	M	52	West	√		
En11	F	49	West			√
En12	F	32	West			√
En13	F	46	East	√	√	
En14	M	40	East	√	√	√
En15	M	54	West			√
En16	F	34	West			√†
En17	M	40	West			√
En18	M	37	West			√
En19	F	48	East			√
En20	M	29	West			√
En21	F	44	West	√	√	
En22	M	32	West			√
En23	M	51	East	√	√	
En24	M	51	West	√	√	
En25	F	45	West			√
En26	F	32	West			√†
En27	F	52	West			√†
En28	M	45	West	√	√	√†

* En01 had just finished a course in intermediate French at the time of recording. En10 has travelled extensively and spent several years in the Malagasy Republic and West Africa; he speaks some French, Malagasy and Hausa, "enough to get by". Other subjects are monolinguals.

† Subjects checked under the *Synthetic* heading and marked with "†" performed a second /bV/ perceptual task in order to provide data to test the validity of the first.

APPENDIX B

SYNTHETIC CONTINUUM DETAILS

Consonantal Transitions

In the continuum used for this study, non-zero amplitudes of all resonant frequencies began at the 5-ms point in the signals. For all tokens, F0 started at 120 Hz and decreased linearly to 100 Hz at the end of the vowel (T=195 ms). F1 began at 200 Hz and reached its target value of 250 Hz at T=30 ms. F2 and F3 reached their target values at T=50 ms. In all cases the progression between the starting and target points was linear. Table 17, below, shows these initial and target values for F2 and F3.

Table 17: Initial and target values (in Hz) of F2 and F3 for the 20 members of the synthetic continuum in /bV/ and /dV/ environments.

	/bV/				/dV/			
	F2		F3		F2		F3	
Token	5 ms	50 ms	5 ms	50 ms	5 ms	50 ms	5 ms	50 ms
1	660	500	1900	2300	1165	500	2417	2300
2	703	600	1900	2300	1214	600	2417	2300
3	746	700	1900	2300	1262	700	2417	2300
4	789	800	1900	2300	1311	800	2417	2300
5	833	900	1900	2300	1359	900	2417	2300
6	876	1000	1900	2300	1408	1000	2417	2300
7	919	1100	1900	2300	1456	1100	2417	2300
8	963	1200	1900	2300	1505	1200	2417	2300
9	1006	1300	1900	2300	1554	1300	2417	2300
10	1049	1400	1900	2300	1602	1400	2417	2300
11	1093	1500	1900	2300	1651	1500	2417	2300
12	1136	1600	1900	2300	1699	1600	2417	2300
13	1179	1700	1900	2300	1748	1700	2417	2300
14	1222	1800	1900	2300	1796	1800	2417	2300
15	1266	1900	2040	2440	1845	1900	2503	2440
16	1309	2000	2180	2580	1894	2000	2590	2580
17	1352	2100	2320	2720	1942	2100	2676	2720
18	1396	2200	2460	2860	1991	2200	2763	2860
19	1439	2300	2600	3000	2039	2300	2849	3000
20	1482	2400	2740	3140	2088	2400	2936	3140

Table 18: English and French high-vowel production means listed beside formant values of their closest matches in the synthetic continuum. Production means for each vowel are computed from the values taken from male speakers across the three consonantal environments, /bVb/, /gVg/ and /dVd/. "Token No." refers to the identification number of the selected item in the synthetic continuum.

English

	/u/		/i/	
	Prod. Means	Token No. 8	Prod. Means	Token No. 19
F1	319	250	264	250
F2	1226	1200	2358	2300
F3	2296	2300	2923	3000

French

	/u/		/y/		/i/	
	Prod. Means	Token No. 3	Prod. Means	Token No. 14	Prod. Means	Token No. 19
F1	300	250	282	250	245	250
F2	728	700	1820	1800	2243	2300
F3	2304	2300	2218	2300	2950	3000

APPENDIX C

ACOUSTICAL DATA

Table 19: F2 values of female speakers for English /u/ in three consonantal environments.

/bub/	Token Number										Across Tokens	
Ss	1	2	3	4	5	6	7	8	9	10	Mn	S.D.
En01		1287	1162	1326	1398	1496	1221	1247	1424	1254	1313	108
En03	1293	1391	1065	1300	1202	1515	1136	1149	1319	1274	1264	132
En09	1339	1385	1391	1365	1561	1463	1313	1502	1450	1443	1421	77
En13	1182	1345	1182	1365	1287	1221	1176	1313	1241	1228	1254	70
En21	1515	1404	1411	1509	1398	1502	1228		1469	1528	1440	95

/gug/	Token Number										Across Tokens	
Ss	1	2	3	4	5	6	7	8	9	10	Mn	S.D.
En01	1463	1404	1535	1482	1456	1482	1437	1600	1580	1476	1492	62
En03	1136	1241	1450	1313	1437	1313	1522	1411	1391		1357	118
En09	1535	1561	1535	1489	1509	1600	1587	1613	1580	1567	1558	40
En13		1574	1365			1450	1502	1548	1385	1515	1477	80
En21	1476	1443	1391	1554	1482	1476	1593	1443	1476	1593	1493	67

/dud/	Token Number										Across Tokens	
Ss	1	2	3	4	5	6	7	8	9	10	Mn	S.D.
En01	1763	1816	1763	1848	1809	1744	1561	1705	1691	1763	1746	81
En03	1770	1482	1443	1528	1757	1678	1691	1776	1698	1476	1630	133
En09	1652	1567	1770	1796	1835	1789	1946	1626	1731	1737	1745	110
En13	1548	1770	1639	1652	1561	1613	1476	1528	1548	1489	1582	88
En21	1855	1816	1946	1829	1927	1796	1953	1907	1744	1691	1846	88

Table 20: F2 values of male speakers for English /u/ in three consonantal environments.

/bub/	Token Number										Across Tokens	
Ss	1	2	3	4	5	6	7	8	9	10	Mn	S.D.
En05	1038	1078	1143	1032	1169	1156	1195	1136	1202	1130	1128	60
En07	1019	993	980	1071	986	947	1051	1045	1065	993	1015	42
En10	954	823	980	1006	940	862	921	927	999	1032	944	65
En14	1123	1104	1143	1104	1045	1215	1176	1195	1176	1123	1140	51
En23	927	954	901	927	901	960	954	1019	914	967	942	36
En24	1149	1130	1143	1104	1071	1025	1130	1012	1110	1006	1088	56
En28	1071	1084		1117	1169		1143	1176	1071	1176	1126	46

/gug/	Token Number										Across Tokens	
Ss	1	2	3	4	5	6	7	8	9	10	Mn	S.D.
En05	1280	1221	1202	1247	1228	1221	1332	1215	1260	1280	1249	40
En07		1143	1058	1071	1097	1110	1189	1130	1091	1123	1112	40
En10	1045	1012	973	1091	1038	1071	1058	1058	1045	1091	1048	36
En14	1234		1319	1274	1254	1293	1254	1260	1241	1293	1269	28
En23	1110	1084	1019	1228	1104	1123		1097	1071	1097	1104	55
En24	1300	1234	1215	1260	1241	1287	1215	1221	1247	1208	1243	31
En28	1274	1306	1326	1352	1032		1228	1385	1247	1254	1267	102

/dud/	Token Number										Across Tokens	
Ss	1	2	3	4	5	6	7	8	9	10	Mn	S.D.
En05	1509	1319	1535	1450	1450	1535	1417	1489	1463	1437	1460	64
En07	1620	1437	1593	1398	1391	1476	1496	1476	1456	1398	1474	79
En10	1306	1306	1417	1293	1254	1306	1339	1339	1319	1306	1319	42
En14	1319	1358	1463	1391	1574	1515	1424	1509	1326	1450	1433	85
En23	1339	1411	1424	1424	1463	1496	1241	1489	1254	1306	1384	94
En24	1522	1476	1496	1496	1417	1371	1463	1424	1476	1404	1454	48
En28	1496	1482	1456	1639	1587		1646	1509	1574	1600	1554	70

Table 21: F2 values of female speakers for English /i/ in three consonantal environments.

/bib/	Token Number					Across Tokens	
Ss	1	2	3	4	5	Mn	S.D.
En01	2737	2699	2782	2616	2737	2714	62
En03	2842	2707	2646	2684	2624	2701	85
En09	2646	2405		2639	2639	2582	118
En13	2639	2571	2458	2488	2654	2562	88
En21	2639	2646	2533	2488	2556	2572	69

/gig/	Token Number					Across Tokens	
Ss	1	2	3	4	5	Mn	S.D.
En01	2752	2759	2722	2752	2729	2743	16
En03	2729	2759	2737	2842	2812	2776	49
En09	2639	2759	2676	2699	2631	2681	52
En13	2511	2594	2556	2571	2616	2570	40
En21	2556	2496	2563	2639	2480	2547	63

/did/	Token Number					Across Tokens	
Ss	1	2	3	4	5	Mn	S.D.
En01	2744	2767	2857	2722	2699	2758	61
En03	2857		2790	2797	2805	2812	30
En09	2714	2714	2676		2759	2716	34
En13	2646	2631	2639	2624	2586	2625	23
En21	2676	2699	2594	2594	2571	2627	57

Table 22: F2 values of male speakers for English /i/ in three consonantal environments.

/bib/	Token Number					Across Tokens	
Ss	1	2	3	4	5	Mn	S.D.
En05	2194	2269	2239	2179	2217	2220	36
En07	2194	2284	2375	2292	2277	2284	64
En10	2511	2435	2503	2503	2398	2470	51
En14		2073	2073	2073	2043	2066	15
En23	2284		2315	2262	2277	2285	22
En24	2330	2299	2315	2292	2315	2310	15
En28	2737	2699		2782	2737	2739	34

/gig/	Token Number					Across Tokens	
Ss	1	2	3	4	5	Mn	S.D.
En05	2307	2201	2194	2262	2435	2280	98
En07	2299	2194	2367	2277	2262	2280	63
En10	2420	2473	2518	2375	2375	2432	63
En14	2028	2096	2066		2058	2062	28
En23	2277	2284	2292	2307	2315	2295	16
En24	2390	2360	2398	2360	2375	2377	17
En28	2722	2752	2729	2759	2699	2732	24

/did/	Token Number					Across Tokens	
Ss	1	2	3	4	5	Mn	S.D.
En05	2239	2284	2224	2254	2262	2253	23
En07	2239	2390	2299	2360	2337	2325	58
En10	2526	2480	2465	2594	2609	2535	65
En14	2194	2119	2217	2194	2149	2175	40
En23	2284	2322	2284	2277	2330	2299	25
En24	2367	2367	2337	2375	2330	2355	20
En28	2616	2744		2767	2857	2746	99

Table 23: F1 and F3 means and standard deviations (in italics) for English /u/ and /i/ in three consonantal environments. Statistics are based on measurements taken from 5 tokens of each item (where available) for all female speakers and for 5 of the 7 male speakers.

English /u/

	F1			F3		
Females	/bub/	/dud/	/gug/	/bub/	/dud/	/gug/
En01	314 *13*	317 *11*	326 *8*	2624 *107*	2702 *44*	2723 *60*
En03	404 *81*	377 *30*	425 *84*	2774 *70*	2687 *81*	2735 *135*
En09	350 *7*	350 *17*	365 *34*	2603 *41*	2578 *65*	2597 *62*
En13	386 *8*	395 *20*	413 *13*	2612 *88*	2657 *107*	2714 *93*
En21	380 *39*	428 *86*	398 *59*	2425 *65*	2515 *76*	2467 *51*
MEANS	367 *29*	373 *33*	385 *40*	2607 *74*	2628 *75*	2647 *80*

Males	/bub/	/dud/	/gug/	/bub/	/dud/	/gug/
En05	317 *18*	311 *31*	323 *23*	2232 *24*	2277 *50*	2229 *39*
En07	338 *13*	329 *34*	359 *7*	2322 *53*	2295 *48*	2250 *22*
En10	338 *25*	314 *27*	347 *55*	2443 *44*	2431 *59*	2461 *77*
En14	302 *11*	302 *18*	308 *13*	2204 *50*	2168 *36*	2126 *26*
En23	314 *20*	302 *32*	283 *7*	2404 *45*	2289 *64*	2310 *42*
MEANS	321 *18*	311 *29*	324 *21*	2321 *43*	2292 *51*	2275 *41*

English /i/

	F1			F3		
Females	/bib/	/did/	/gig/	/bib/	/did/	/gig/
En01	314 *7*	320 *13*	308 *8*	3423 *77*	3432 *46*	3375 *36*
En03	410 *69*	373 *51*	383 *25*	3347 *61*	3283 *66*	3314 *95*
En09	351 *19*	369 *31*	347 *21*	3445 *158*	3344 *110*	3419 *107*
En13	389 *7*	377 *0*	389 *13*	3453 *131*	3465 *96*	3468 *95*
En21	413 *47*	428 *67*	380 *52*	3604 *123*	3468 *75*	3438 *61*
MEANS	375 *30*	373 *32*	361 *24*	3455 *110*	3398 *78*	3403 *79*

Males	/bib/	/did/	/gig/	/bib/	/did/	/gig/
En05	223 *25*	250 *23*	250 *20*	3010 *27*	3010 *68*	3076 *41*
En07	271 *21*	283 *20*	271 *30*	2853 *63*	2847 *58*	2820 *107*
En10	250 *13*	274 *34*	265 *13*	3073 *101*	3145 *20*	2958 *72*
En14	294 *19*	283 *27*	271 *17*	2616 *19*	2696 *63*	2605 *26*
En23	253 *19*	268 *20*	253 *27*	3016 *108*	3025 *65*	3094 *56*
MEANS	258 *20*	272 *25*	262 *22*	2913 *64*	2945 *55*	2911 *60*

Table 24: F2 values for French /u/ in three consonantal environments.

	/bub/	Token Number										Across Tokens	
Sex	Ss	1	2	3	4	5	6	7	8	9	10	Mn	S.D.
F	Fr03	875	837	859	859	852	852	837	844	867	867	855	13
F	Fr09	1056	988	1010	1040	920	867	852	822	942	942	944	80
F	Fr16	882	792	882	822	822	746	746	792	746	761	799	52
M	Fr02	626	656	626	633	671	686	626	679	633	611	645	26
M	Fr11	754	746	769	746	686	746	777	746	731	686	739	31

	/gug/	Token Number										Across Tokens	
Sex	Ss	1	2	3	4	5	6	7	8	9	10	Mn	S.D.
F	Fr03	920	859	882	822	814	875	844	829	912	995	875	55
F	Fr09	988	1003	957	935	988	1010	950	995	942	1010	978	29
F	Fr16	844	882	973	912	920	920	920	867	950	829	902	46
M	Fr02	724	731	731	709	686	731	746	686	746	769	726	26
M	Fr11	746	731	746	746	716	777	694	694	739	716	731	26

	/dud/	Token Number										Across Tokens	
Sex	Ss	1	2	3	4	5	6	7	8	9	10	Mn	S.D.
F	Fr03	1040	1040	980	905	1025	920	1003	927	1108	920	987	68
F	Fr09	1078	1010	1101	1093	950	1086	1146	1176	1010	1214	1086	81
F	Fr16	1033	980	1101	1056	1010	1063	988	1056	957	1003	1025	45
M	Fr02	679	731	761	875	746	746	739	746	784	746	755	50
M	Fr11	679	814	731	792	829	769	799	784	754	761	771	44

Table 25: F2 values for French /y/ in three consonantal environments.

	/byb/	Token Number										Across Tokens	
Sex	Ss	1	2	3	4	5	6	7	8	9	10	Mn	S.D.
F	Fr03	1975	2126	2201	2164	1975	2119	2088	2005	1923	1945	2052	99
F	Fr09	2005	2103	2073	2103	2036	2088	2171	2043	2134	2171	2093	56
F	Fr16	2013	2058	2141	2096	2043	2103	2156	2005	2126	2119	2086	53
M	Fr02	1696	1628	1681	1719	1696	1666	1651	1644	1621	1674	1668	32
M	Fr11	1968	1975	1832	1953	1938	1885	1945	1840	1953	1907	1920	52

	/gyg/	Token Number										Across Tokens	
Sex	Ss	1	2	3	4	5	6	7	8	9	10	Mn	S.D.
F	Fr03	2051	2058	1998	2028	2051	2066	1983	2103	2066	2111	2052	41
F	Fr09	2224	2284	2254	2164	2179	2292	2209	2292	2164	2164	2223	55
F	Fr16	2058	2021	2058	2209	2119	2141	2119	2058	2126	2066	2098	55
M	Fr02	1704	1742	1764	1711	1689	1666	1681	1689	1704	1727	1708	30
M	Fr11	1960	1968	1923	1900	1923	1915	1938	1862	1990	1938	1932	36

	/dyd/	Token Number										Across Tokens	
Sex	Ss	1	2	3	4	5	6	7	8	9	10	Mn	S.D.
F	Fr03	2058	1938	2051	2058	2043	2103	2058	2028	2013	2021	2037	43
F	Fr09	2186	2209	2186	2141	2224	2179	2186	2164	2073	2194	2174	42
F	Fr16	2149	2141	2164	2119	2171	2164	2164	2232	2164	2201	2167	31
M	Fr02	1719	1681	1734	1749	1727	1742	1704	1742	1696	1764	1726	26
M	Fr11	1960	1930	1968	1960	1983	1968	1945	2021	1953	2013	1970	29

Table 26: F2 values for French /i/ in three consonantal environments.

	/bib/	Token Number										Across Tokens	
Sex	Ss	1	2	3	4	5	6	7	8	9	10	Mn	S.D.
F	Fr03	2322	2367	2405	2360	2367	2375	2367	2360	2465	2405	2379	38
F	Fr09	2563	2435	2413	2541	2518	2541	2496	2428	2571	2398	2490	66
F	Fr16	2556	2578	2511	2609	2594	2578	2556	2609	2488	2511	2559	43
M	Fr02	2028	2058	2028	2081	2081	2043	2051	2036	2066	2103	2058	25
M	Fr11	2458	2450	2330	2465	2420	2450	2458	2299	2420	2375	2413	59

	/gig/	Token Number										Across Tokens	
Sex	Ss	1	2	3	4	5	6	7	8	9	10	Mn	S.D.
F	Fr03	2480	2390	2390	2496	2556	2480	2413	2548	2420	2413	2459	62
F	Fr09	2465	2503	2420	2609	2450	2480	2511	2450	2480	2563	2493	57
F	Fr16	2714	2661	2556	2526	2692	2556	2646	2578	2661	2639	2623	64
M	Fr02	2058	2021	2013	1968	2096	2088	2021	2073	2073	2043	2045	40
M	Fr11	2413	2511	2382	2450	2382	2413	2465	2428	2413	2337	2419	49

	/did/	Token Number										Across Tokens	
Sex	Ss	1	2	3	4	5	6	7	8	9	10	Mn	S.D.
F	Fr03	2315	2330	2533	2390	2480	2390	2526	2375	2458	2443	2424	76
F	Fr09	2511	2465	2578	2511	2578	2435	2571	2496	2473	2496	2511	50
F	Fr16	2676	2556	2503	2692	2578	2548	2586	2714	2609	2661	2612	70
M	Fr02	2058	2141	1968	2134	2081	2073	2028	2096	2088	2126	2079	53
M	Fr11	2511	2511	2526	2360	2352	2465	2375	2382	2480	2465	2443	68

Table 27: F1 and F3 means and standard deviations (in italics) for French /u/, /y/ and /i/ in three consonantal environments. Statistics are based on measurements taken from 5 tokens of each item for all speakers.

French /u/

	F1			F3		
Females	/bub/	/dud/	/gug/	/bub/	/dud/	/gug/
Fr03	431 *8*	449 *7*	455 *20*	2587 *106*	2624 *41*	2581 *65*
Fr09	476 *38*	476 *29*	528 *18*	2639 *137*	2584 *106*	2690 *88*
Fr16	476 *13*	452 *24*	483 *18*	2639 *87*	2675 *134*	2657 *137*
MEANS	461 *20*	459 *20*	489 *19*	2622 *110*	2628 *94*	2643 *97*
Males	/bub/	/dud/	/gug/	/bub/	/dud/	/gug/
Fr02	274 *27*	277 *20*	286 *28*	2217 *71*	2217 *79*	2108 *59*
Fr11	308 *20*	326 *8*	329 *13*	2434 *70*	2461 *39*	2385 *22*
MEANS	291 *24*	302 *14*	308 *20*	2325 *71*	2339 *59*	2247 *41*

French /y/

	F1			F3		
Females	/byb/	/dyd/	/gyg/	/byb/	/dyd/	/gyg/
Fr03	452 *18*	434 *7*	446 *8*	2612 *60*	2539 *115*	2455 *49*
Fr09	492 *17*	522 *55*	486 *25*	2581 *81*	2657 *85*	2600 *56*
Fr16	419 *13*	425 *7*	446 *23*	2539 *45*	2575 *72*	2551 *63*
MEANS	454 *16*	460 *23*	459 *19*	2577 *62*	2591 *91*	2535 *56*
Males	/byb/	/dyd/	/gyg/	/byb/	/dyd/	/gyg/
Fr02	262 *27*	265 *20*	280 *13*	2156 *55*	2135 *51*	2078 *20*
Fr11	290 *13*	280 *13*	314 *13*	2313 *25*	2331 *23*	2292 *57*
MEANS	276 *20*	273 *17*	297 *13*	2235 *40*	2233 *37*	2185 *39*

French /i/

	F1			F3		
Females	/bib/	/did/	/gig/	/bib/	/did/	/gig/
Fr03	425 *7*	428 *8*	440 *13*	3254 *111*	3176 *86*	3194 *72*
Fr09	473 *35*	489 *60*	486 *33*	3375 *81*	3426 *76*	3462 *119*
Fr16	401 *31*	425 *17*	428 *23*	3414 *63*	3522 *77*	3438 *110*
MEANS	433 *24*	447 *28*	451 *23*	3347 *85*	3375 *80*	3365 *100*
Males	/bib/	/did/	/gig/	/bib/	/did/	/gig/
Fr02	232 *8*	235 *8*	238 *7*	2889 *68*	2955 *121*	3013 *54*
Fr11	250 *17*	262 *13*	250 *8*	2856 *72*	2964 *117*	3025 *48*
MEANS	241 *13*	249 *11*	244 *8*	2872 *70*	2960 *119*	3019 *51*

APPENDIX D

PERCEPTUAL TEST DATA—SYNTHETIC SIGNALS

Figures in this section show English listeners' identification functions of the vowels /i/ and /u/, and French listeners' identification functions of the vowels /i/, /y/, and /u/ in synthetic signals. Functions are shown for three different consonantal environments. Figures 22 and 23, on the following two pages, show the means for all English and French listeners. Subsequent plots are those for individuals.

Note that the /bV/ functions cover a range of only 800-2225 Hz (see pp. 142-143). In order to allow for comparison among environments, however, they are plotted on the full 500-2400 Hz scale.

In order to allow maximum space for the graphs themselves, the axes are not labelled. The abscissa gives decreasing values of F2 in Hz; values on the ordinate are proportions in %. Vertical dashed lines plot the calculated boundaries. (See p. 142 for the formulas used in the computation of these crossover values.)

The data from 5 English listeners were not included in the analysis. Those from En18 (p. 250) were excluded because of the irregularity of the /V/ and /bV/ functions, those from En02 (p. 238), En07 (p. 242), En08 (p. 243), and En17 (p. 249) because of the low boundary values across environments.

Figure 22: Mean identification percentage functions of the vowels /i/ and /u/ in synthetic signals by Canadian English listeners. (See p. 234 for explanatory details.)

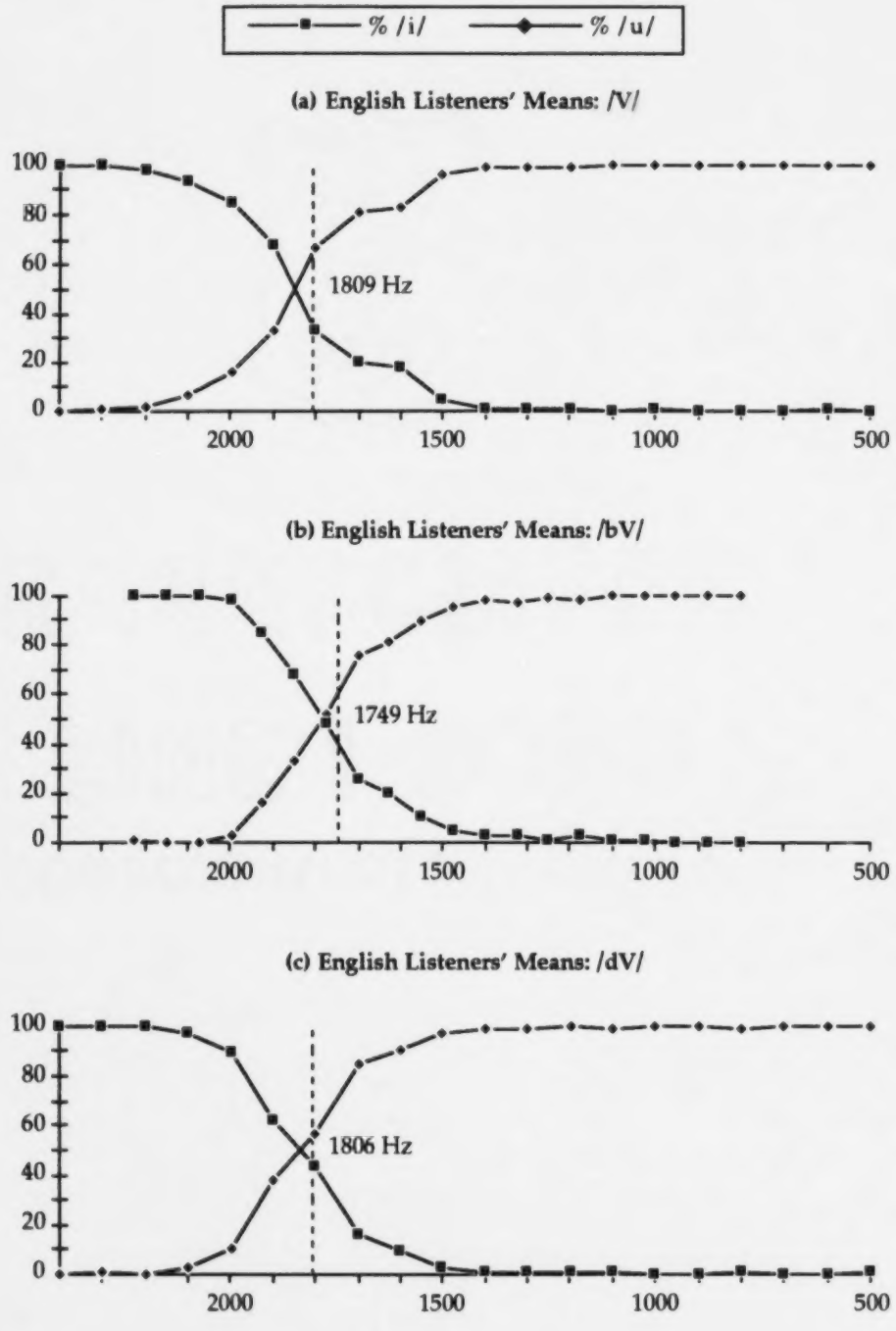
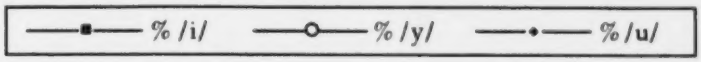
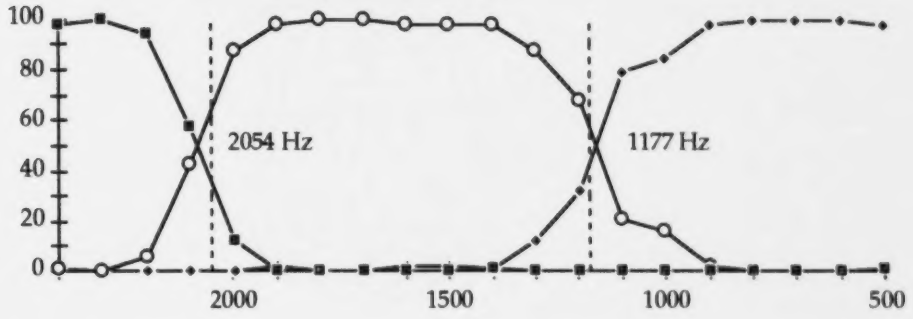


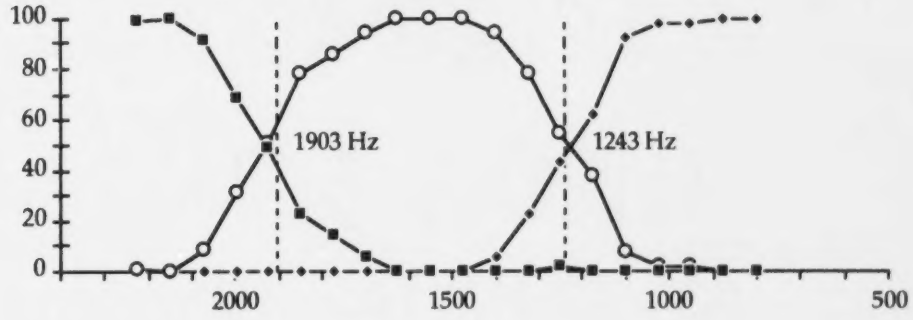
Figure 23: Mean identification percentage functions of the vowels /i/, /y/ and /u/ in synthetic signals by French listeners. (See p. 234 for explanatory details.)



(a) French Listeners' Means: /V/



(b) French Listeners' Means: /bV/



(c) French Listeners' Means: /dV/

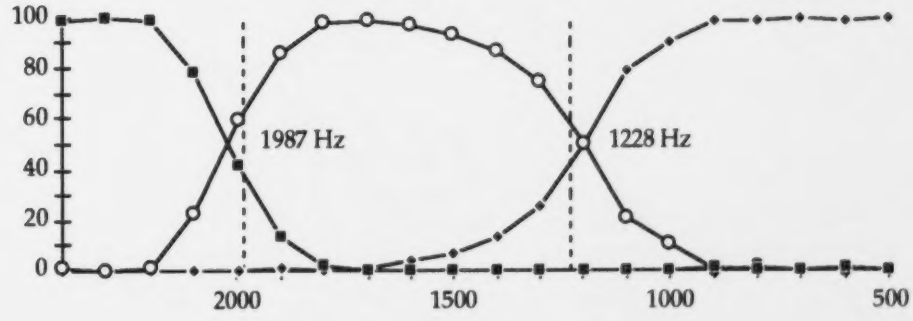
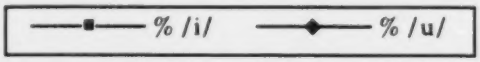
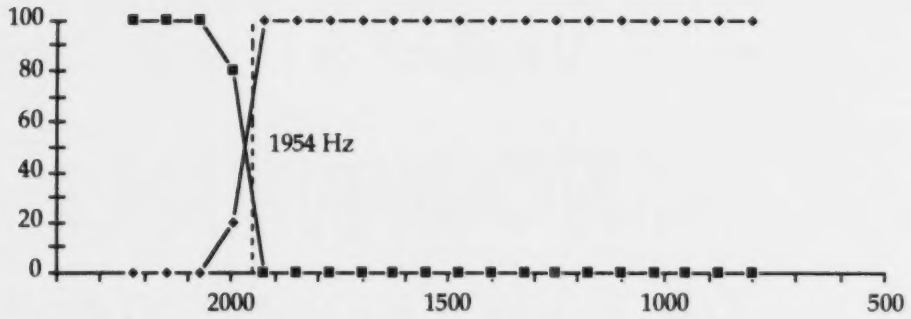


Figure 24: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En01. (See p. 234 for explanatory details.)



(a) English Listener En01: /V/

(b) English Listener En01: /bV/



(c) English Listener En01: /dV/

Figure 25: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En02. (See p. 234 for explanatory details.)

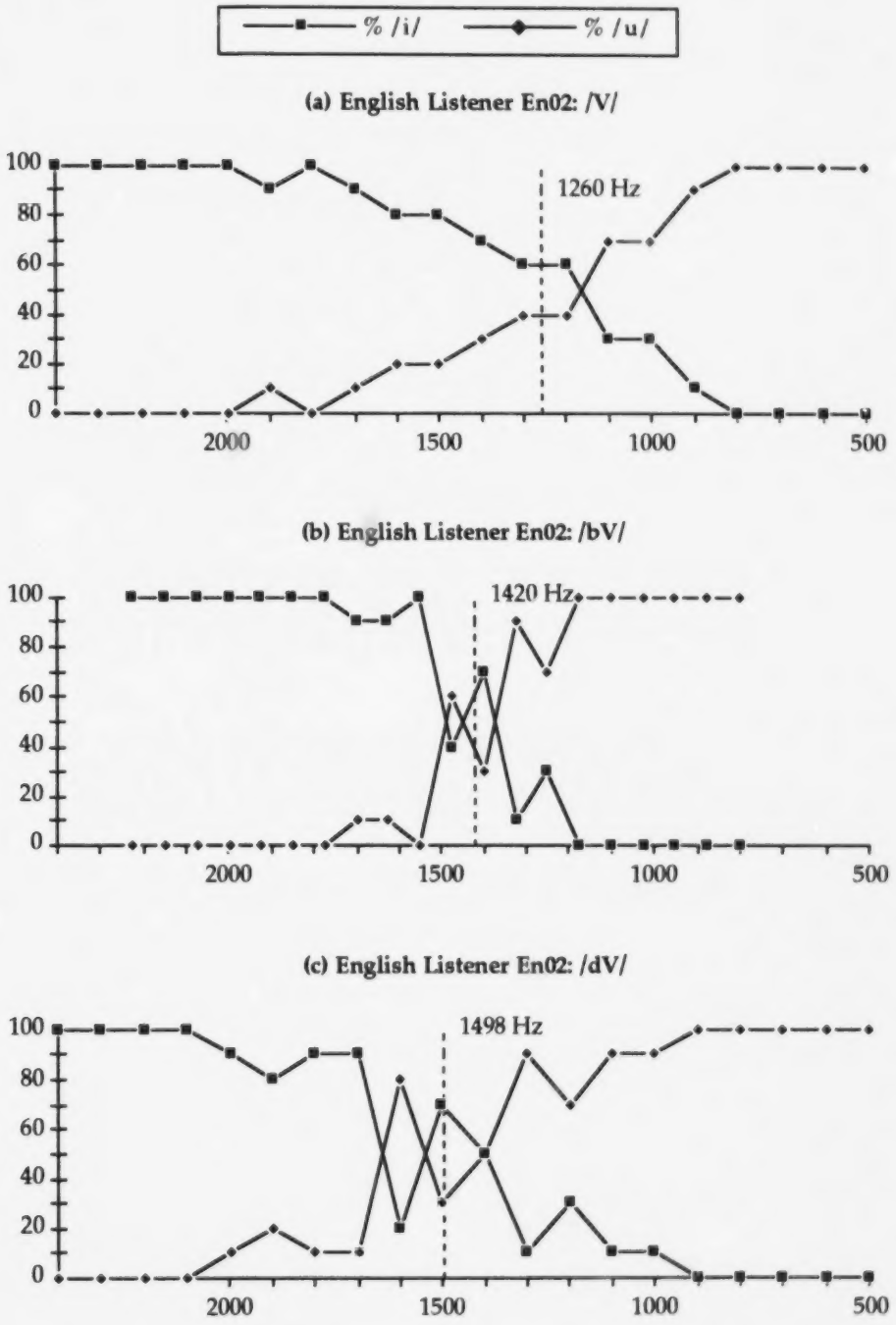
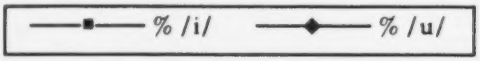
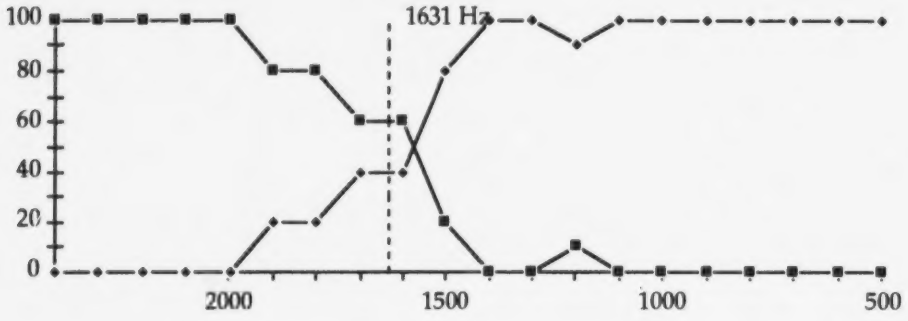


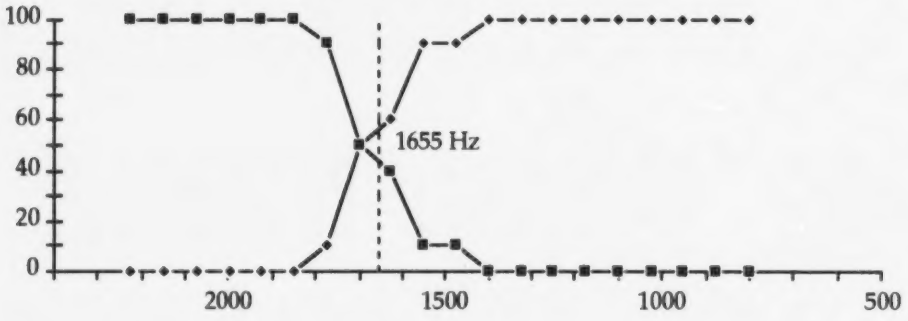
Figure 26: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En03. (See p. 234 for explanatory details.)



(a) English Listener En03: /V/



(b) English Listener En03: /bV/



(c) English Listener En03: /dV/

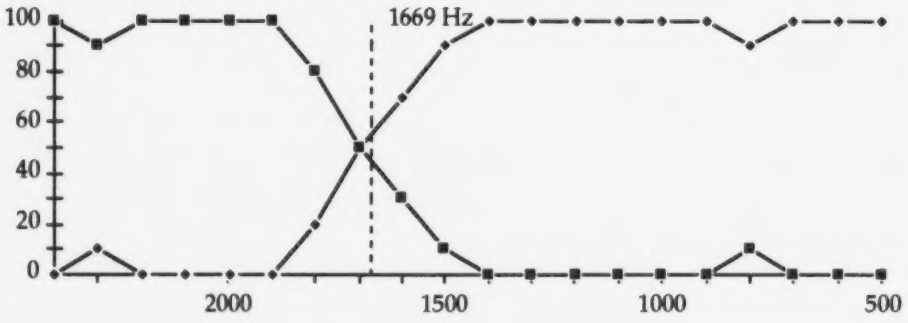
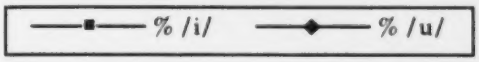
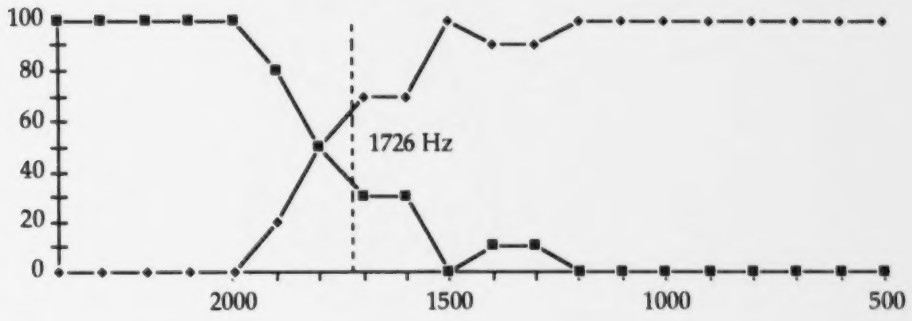


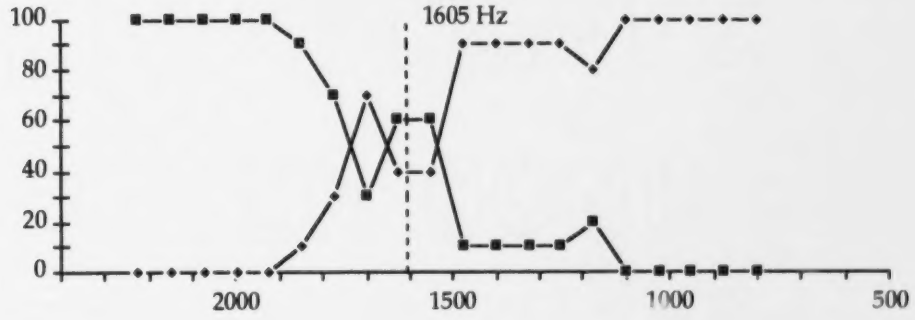
Figure 27: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En04. (See p. 234 for explanatory details.)



(a) English Listener En04: /V/



(b) English Listener En04: /bV/



(c) English Listener En04: /dV/

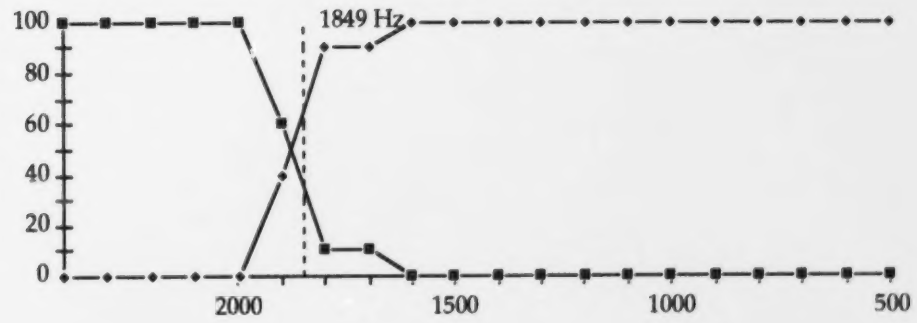


Figure 28: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En06. (See p. 234 for explanatory details.)

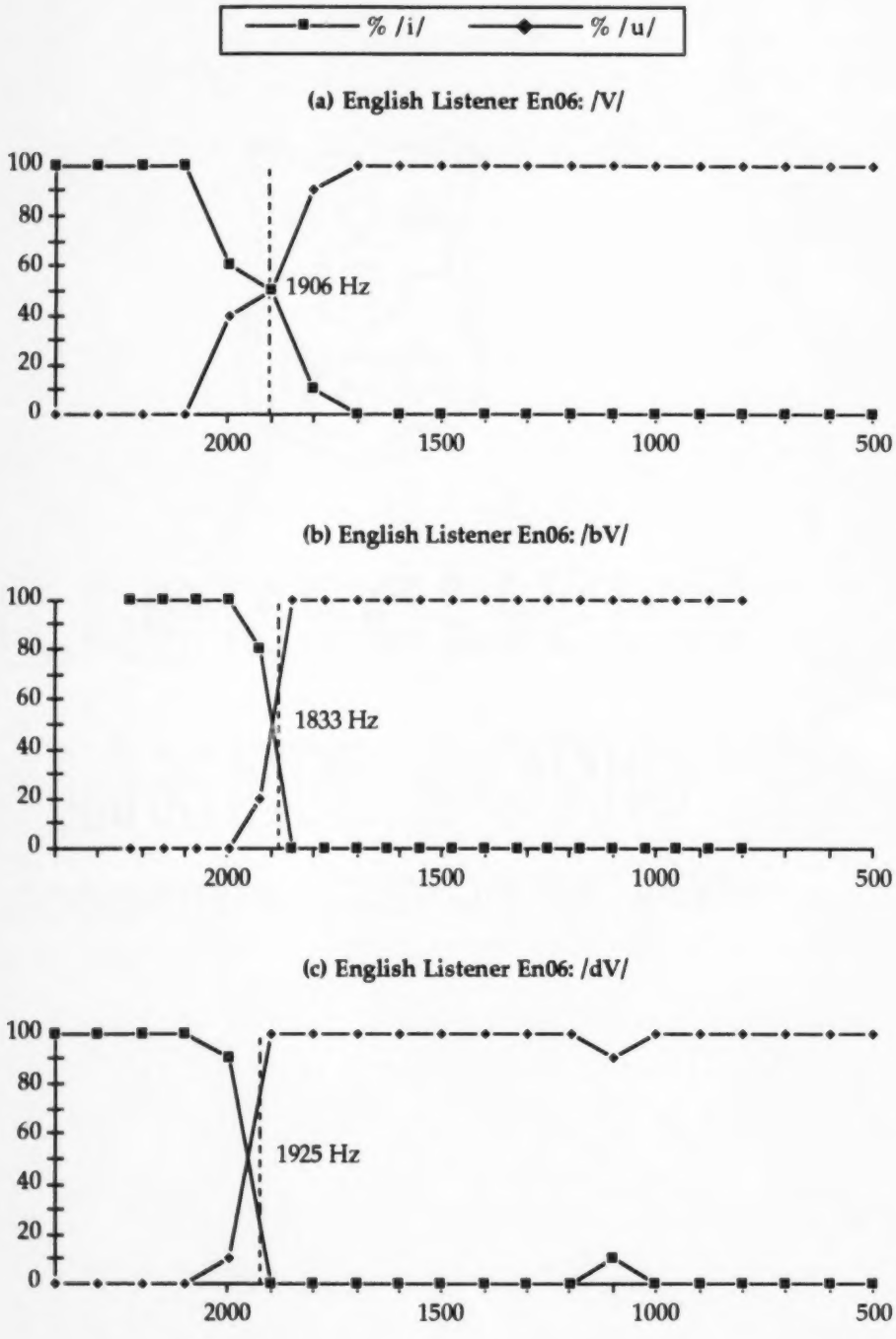
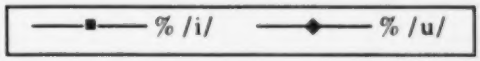
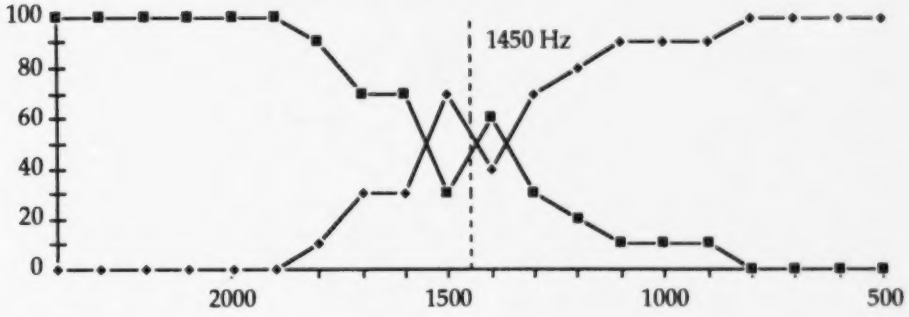


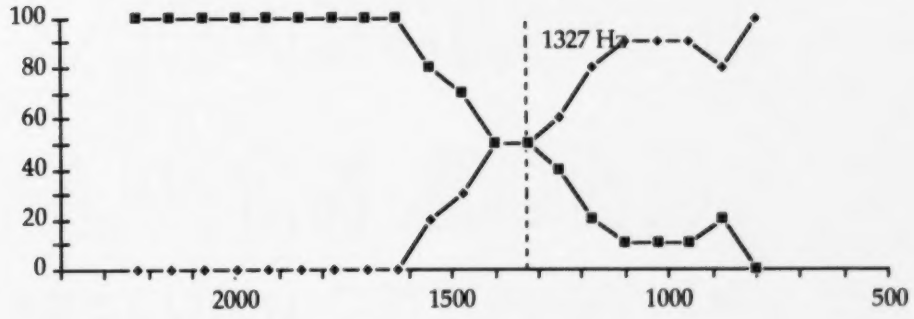
Figure 29: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En07. (See p. 234 for explanatory details.)



(a) English Listener En07: /V/



(b) English Listener En07: /bV/



(c) English Listener En07: /dV/

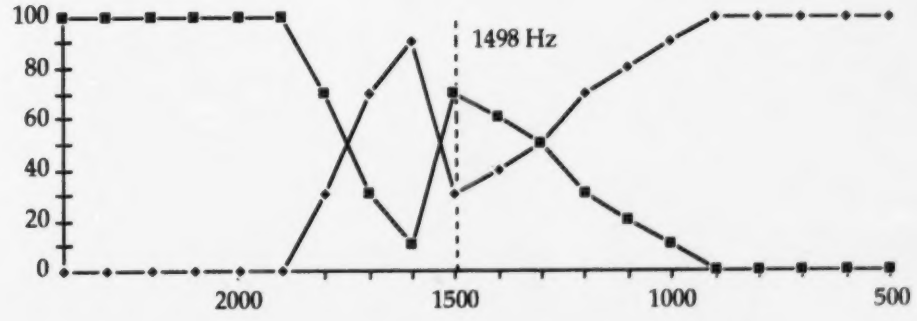
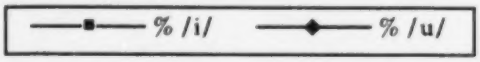
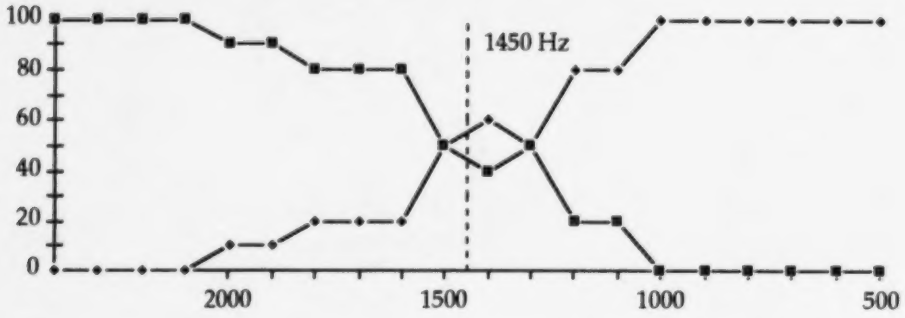


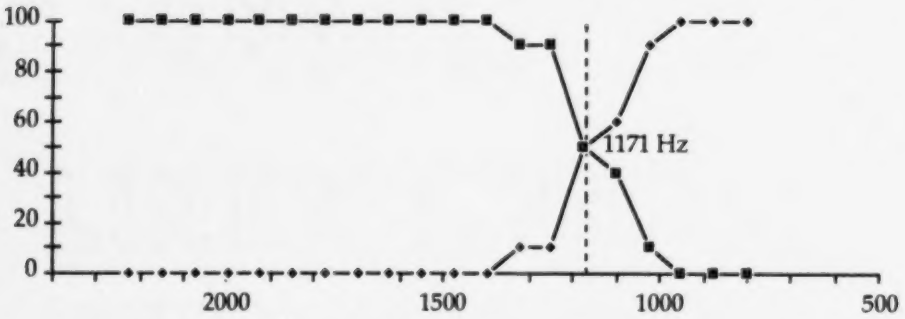
Figure 30: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En08. (See p. 234 for explanatory details.)



(a) English Listener En08: /V/



(b) English Listener En08: /bV/



(c) English Listener En08: /dV/

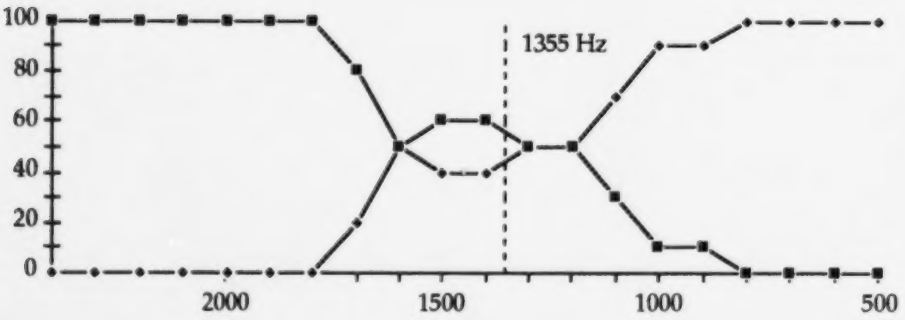
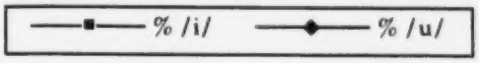
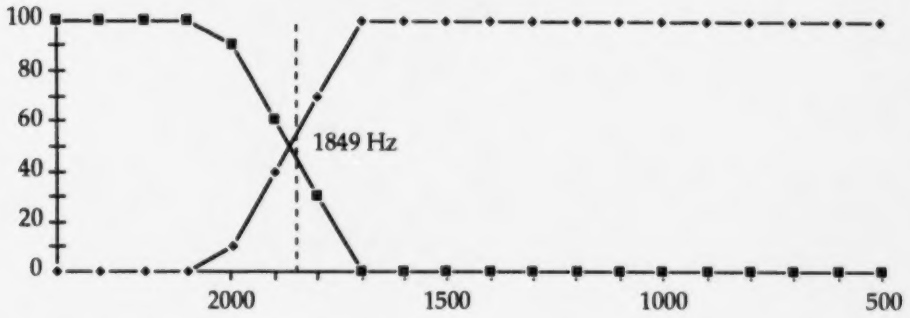


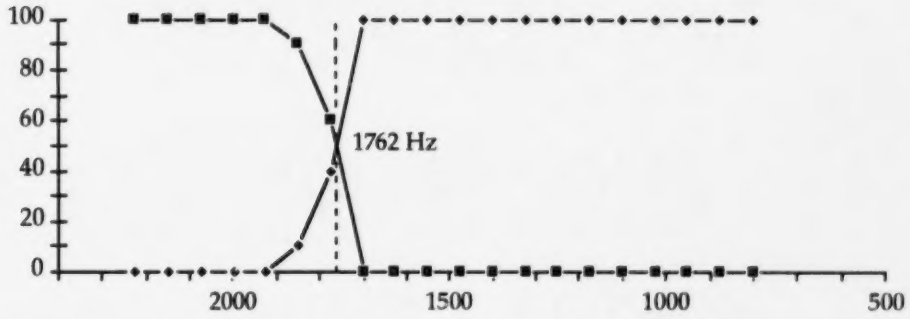
Figure 31: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En11. (See p. 234 for explanatory details.)



(a) English Listener En11: /V/



(b) English Listener En11: /bV/



(c) English Listener En11: /dV/

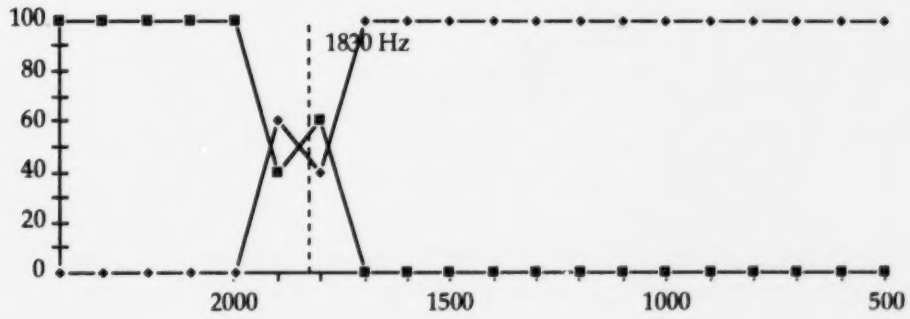
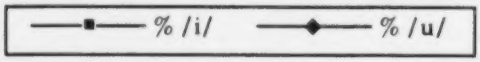
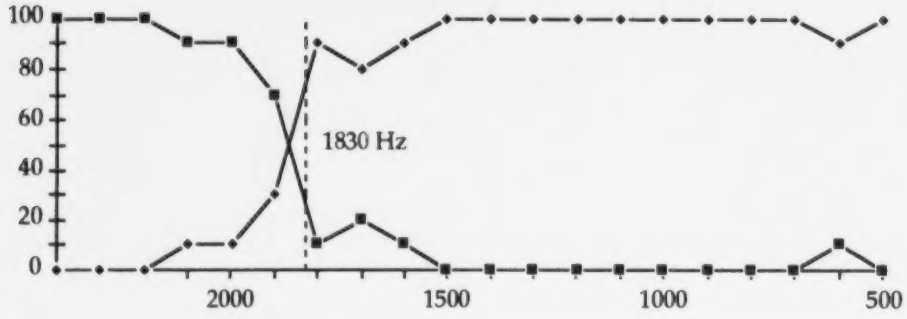


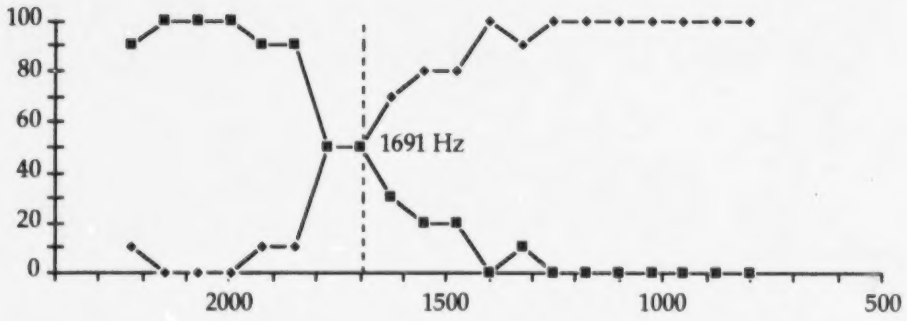
Figure 32: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En12. (See p. 234 for explanatory details.)



(a) English Listener En12: /V/



(b) English Listener En12: /bV/



(c) English Listener En12: /dV/

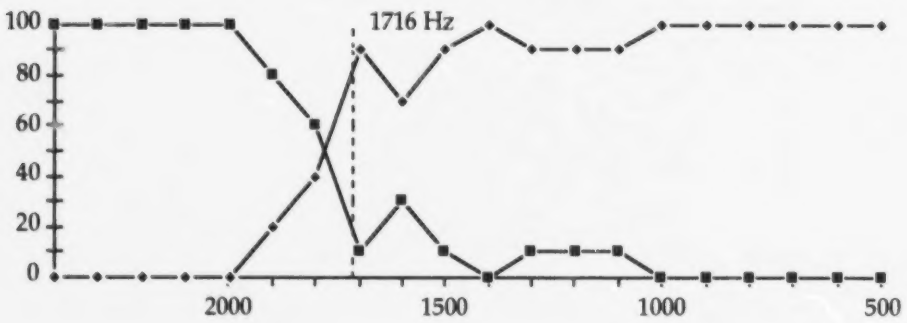
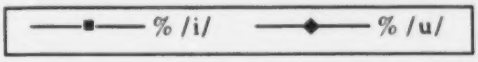
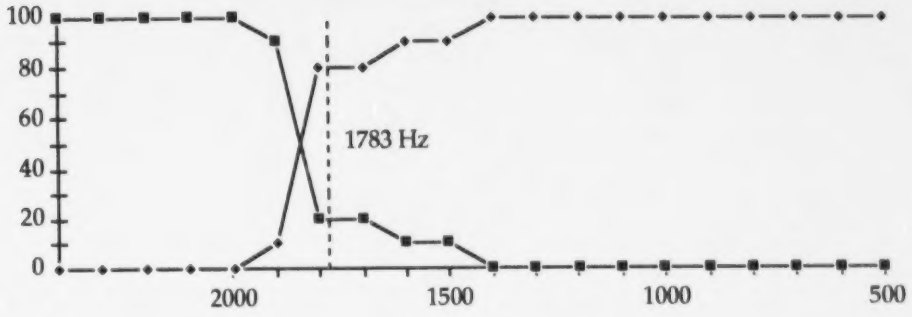


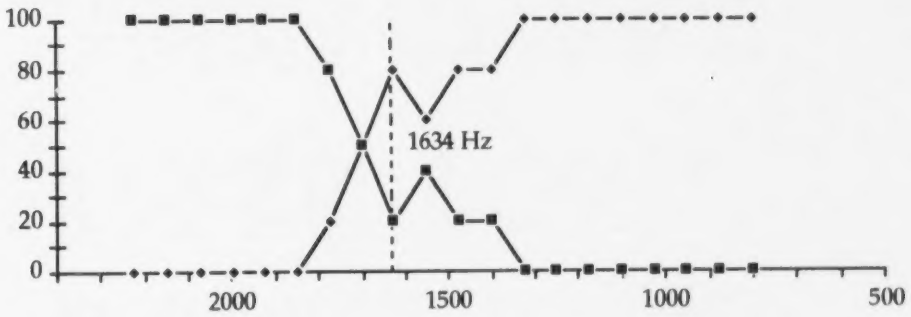
Figure 33: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En14. (See p. 234 for explanatory details.)



(a) English Listener En14: /V/



(b) English Listener En14: /bV/



(c) English Listener En14: /dV/

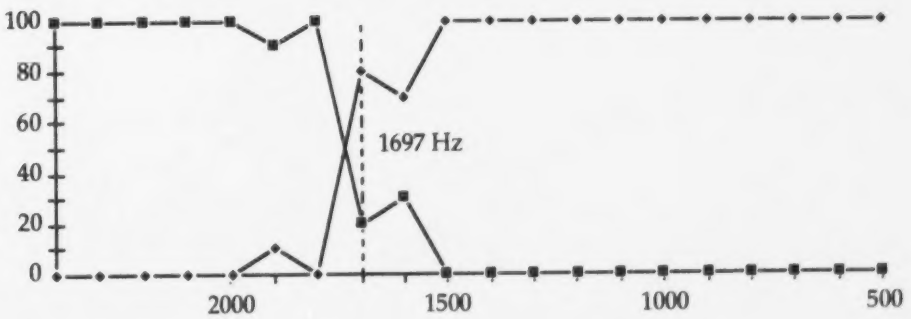
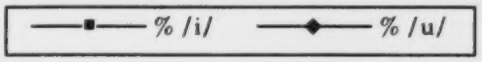
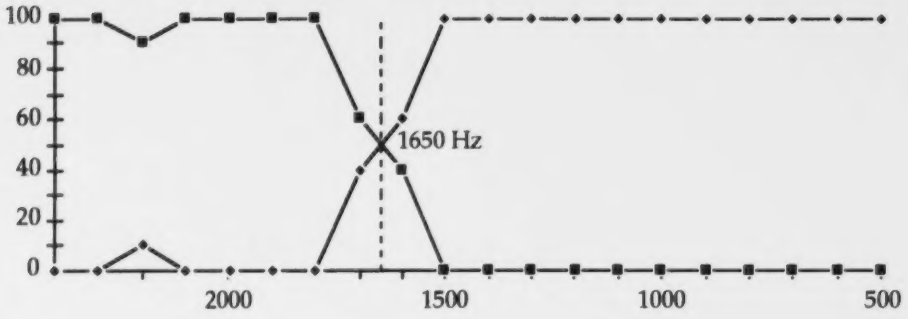


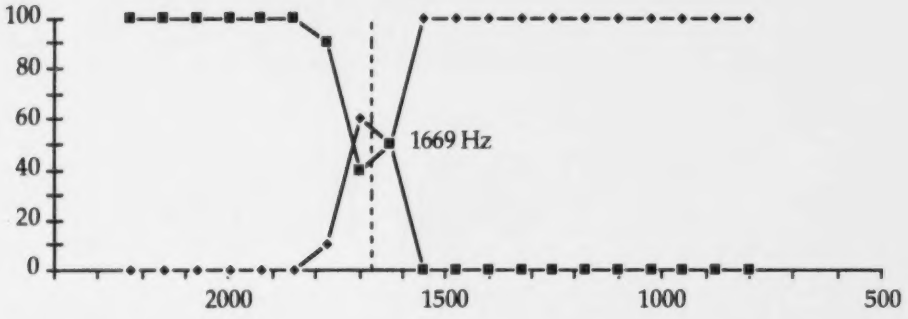
Figure 34: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En15. (See p. 234 for explanatory details.)



(a) English Listener En15: /V/



(b) English Listener En15: /bV/



(c) English Listener En15: /dV/

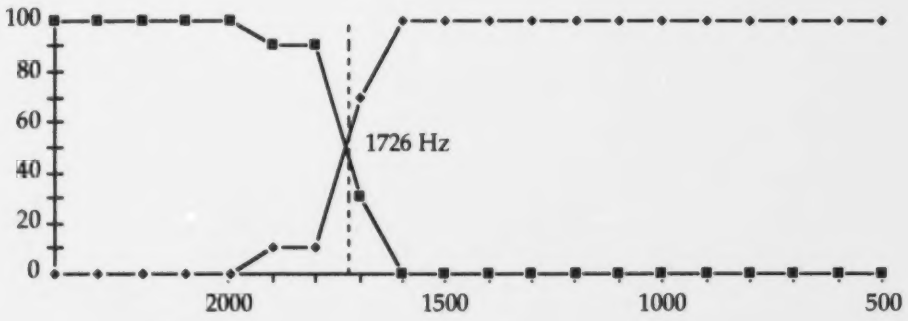
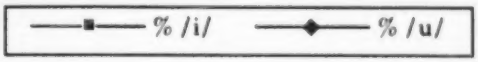
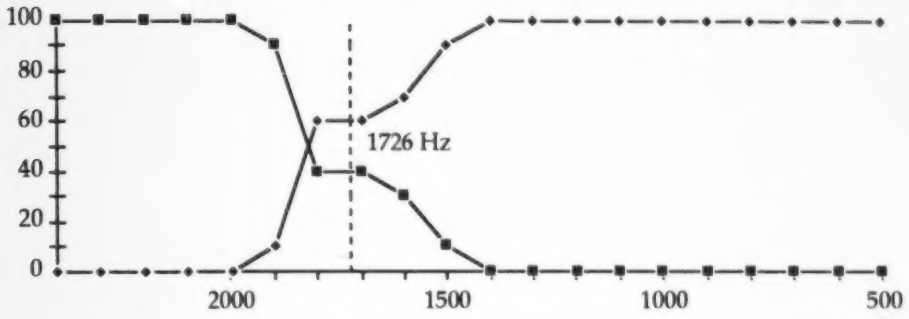


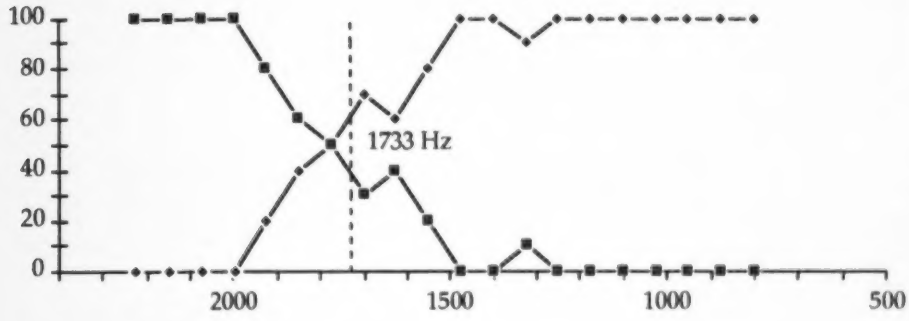
Figure 35: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En16. (See p. 234 for explanatory details.)



(a) English Listener En16: /V/



(b) English Listener En16: /bV/



(c) English Listener En16: /dV/

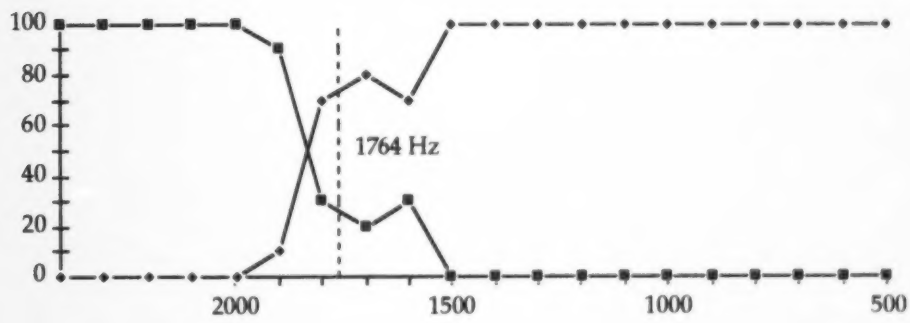


Figure 36: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En17. (See p. 234 for explanatory details.)

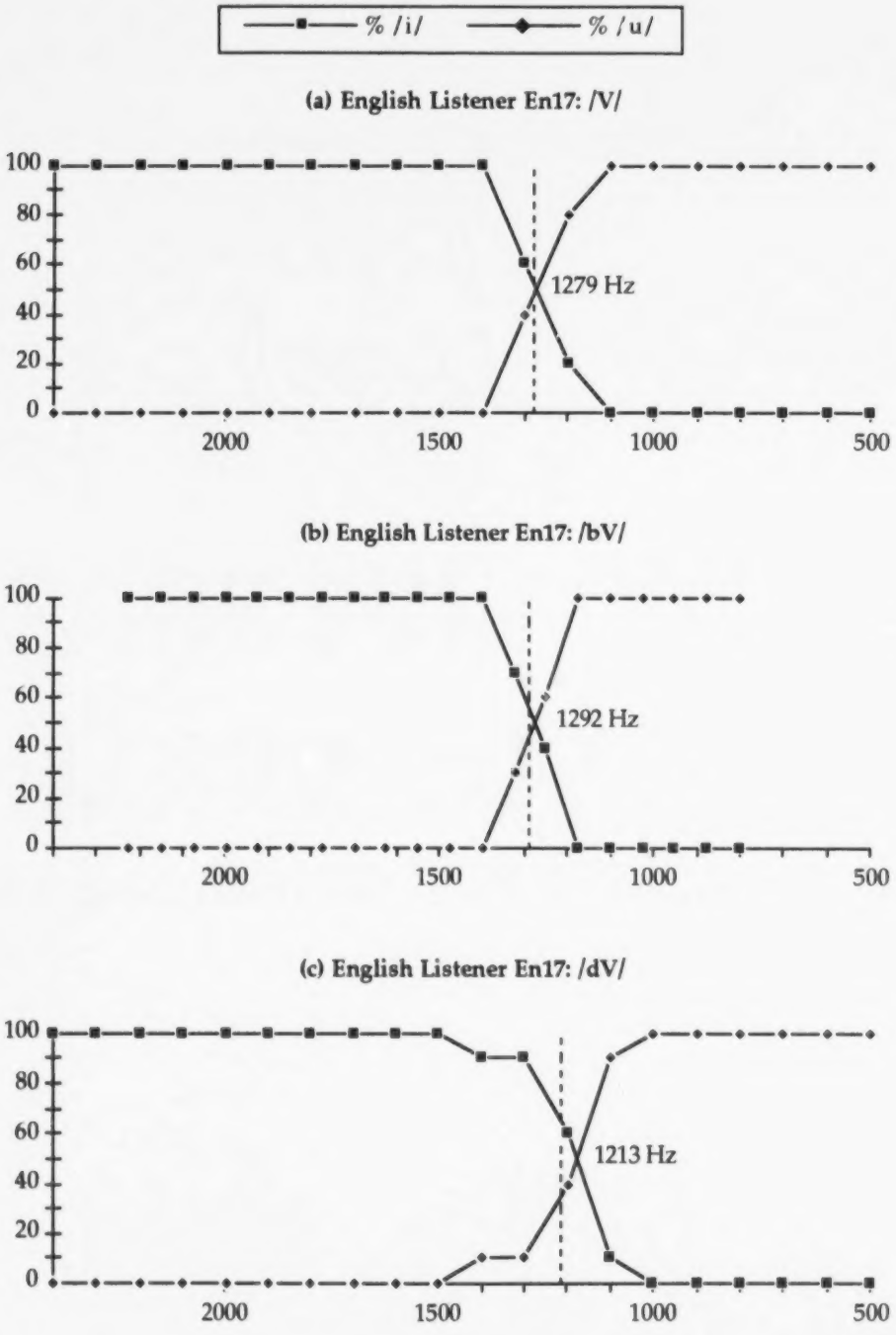
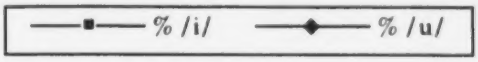
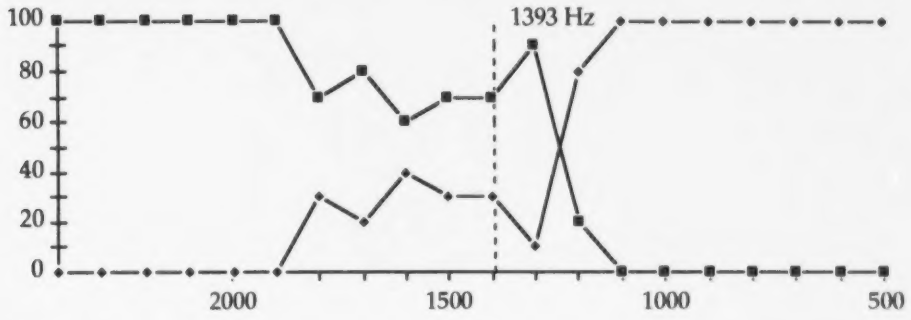


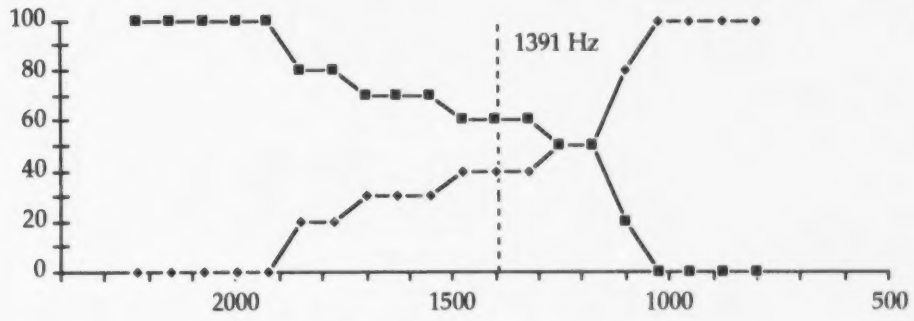
Figure 37: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En18. (See p. 234 for explanatory details.)



(a) English Listener En18: /V/



(b) English Listener En18: /bV/



(c) English Listener En18: /dV/

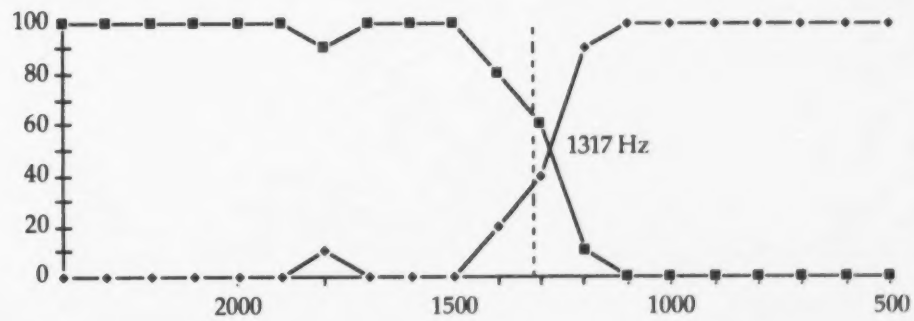
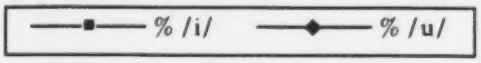
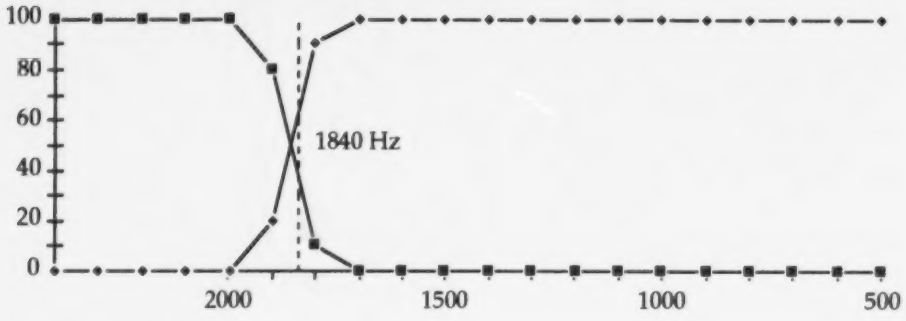


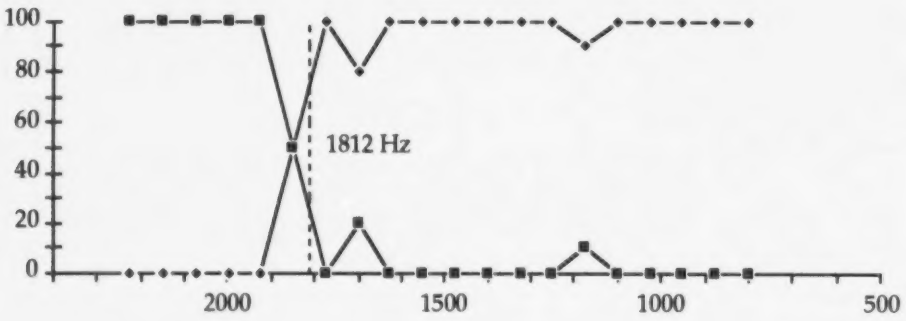
Figure 38: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En19. (See p. 234 for explanatory details.)



(a) English Listener En19: /V/



(b) English Listener En19: /bV/



(c) English Listener En19: /dV/

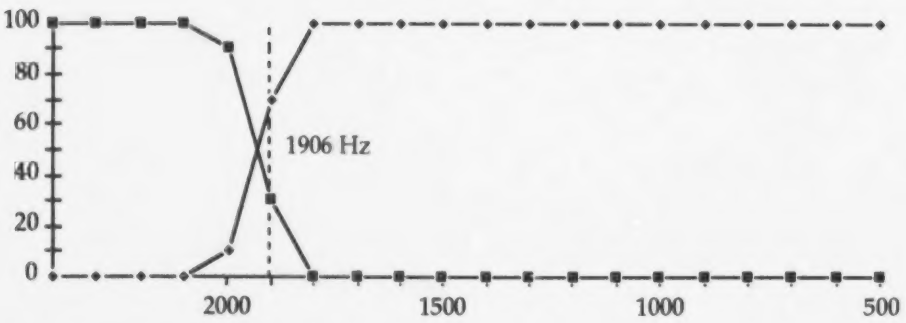
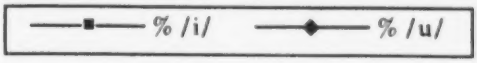
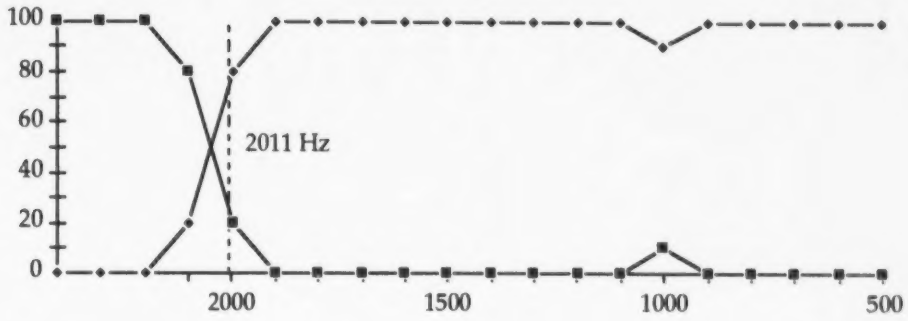


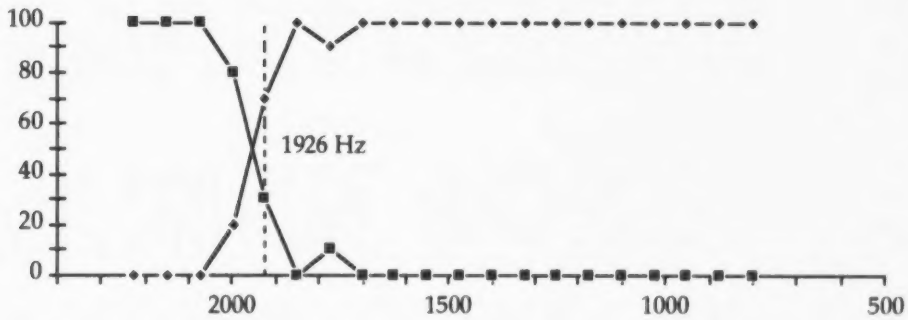
Figure 39: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En20. (See p. 234 for explanatory details.)



(a) English Listener En20: /V/



(b) English Listener En20: /bV/



(c) English Listener En20: /dV/

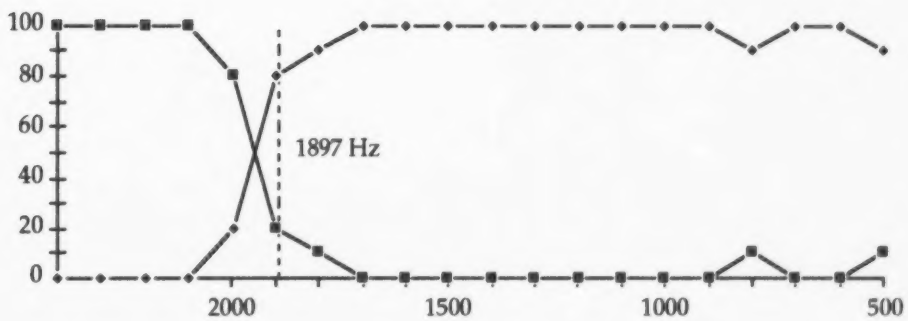
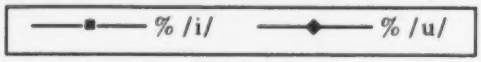
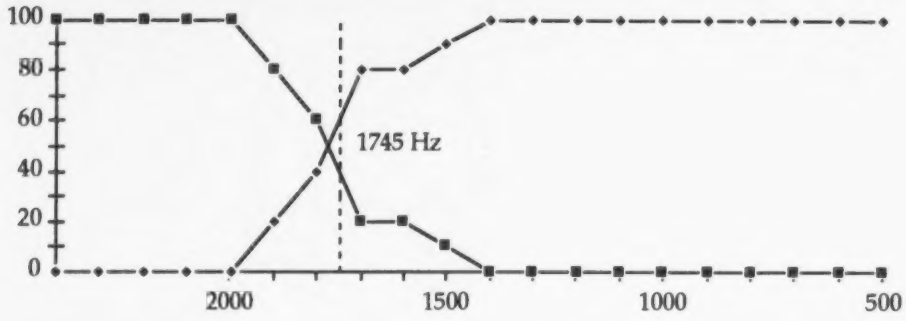


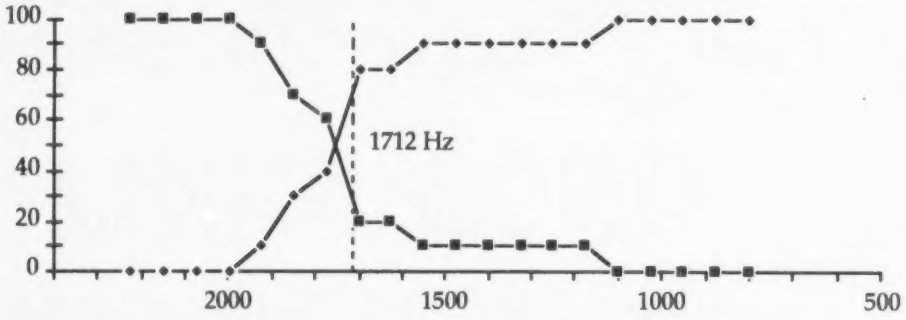
Figure 40: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En22. (See p. 234 for explanatory details.)



(a) English Listener En22: /V/



(b) English Listener En22: /bV/



(c) English Listener En22: /dV/

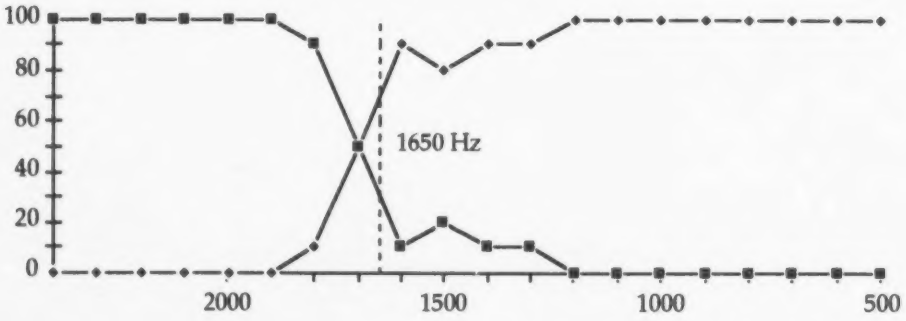
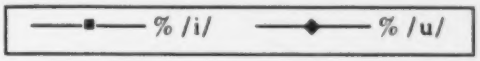
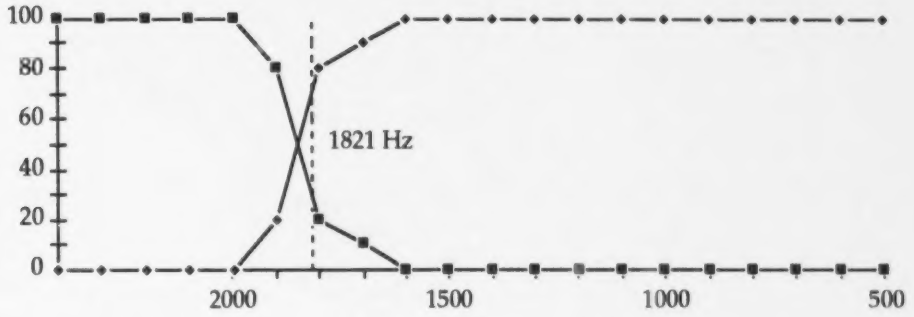


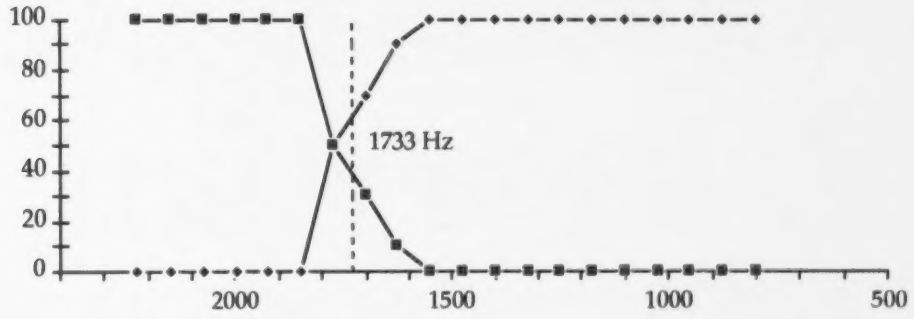
Figure 41: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En25. (See p. 234 for explanatory details.)



(a) English Listener En25: /V/

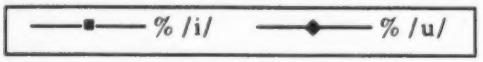


(b) English Listener En25: /bV/

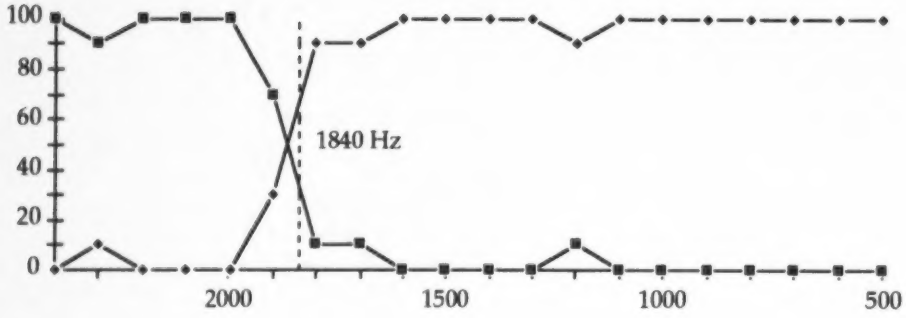


(c) English Listener En25: /dV/

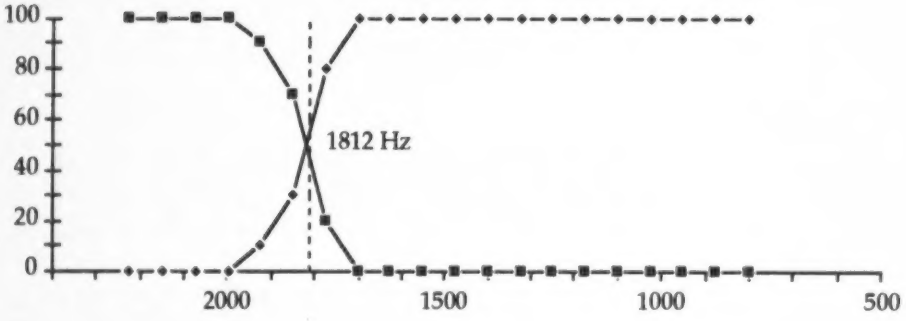
Figure 42: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En26. (See p. 234 for explanatory details.)



(a) English Listener En26: /V/



(b) English Listener En26: /bV/



(c) English Listener En26: /dV/

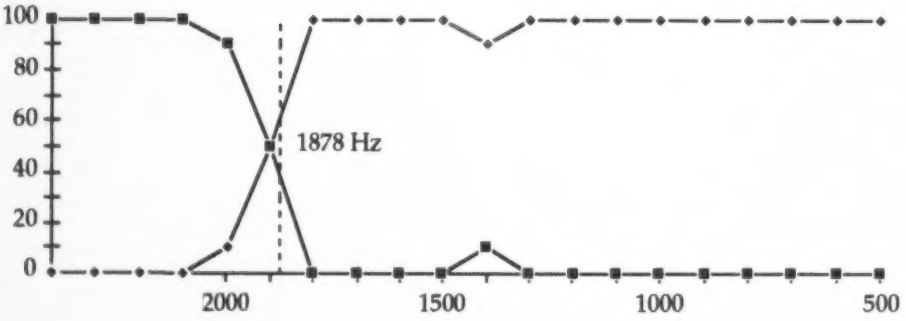
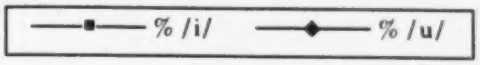
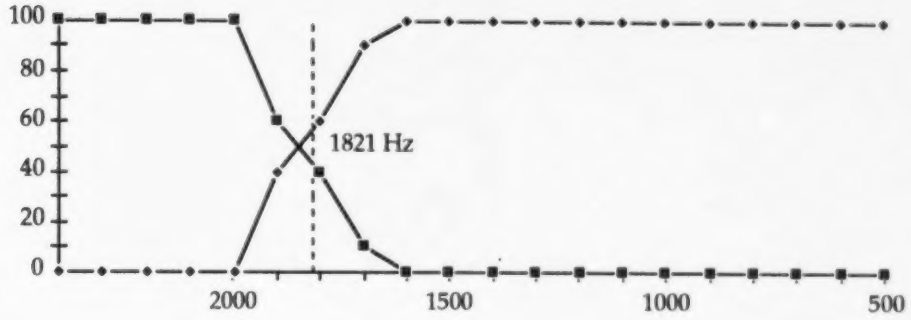


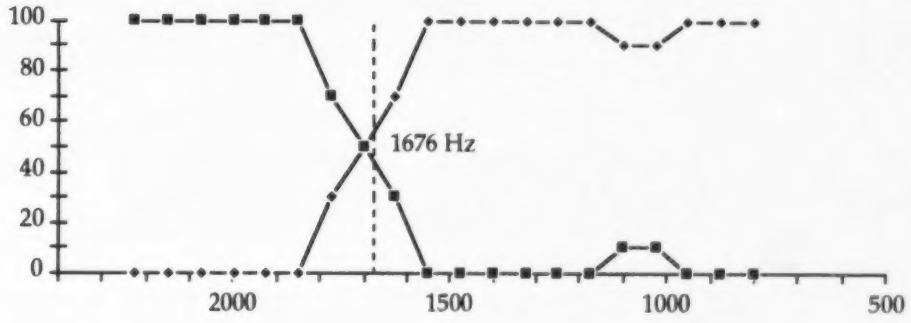
Figure 43: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En27. (See p. 234 for explanatory details.)



(a) English Listener En27: /V/



(b) English Listener En27: /bV/



(c) English Listener En27: /dV/

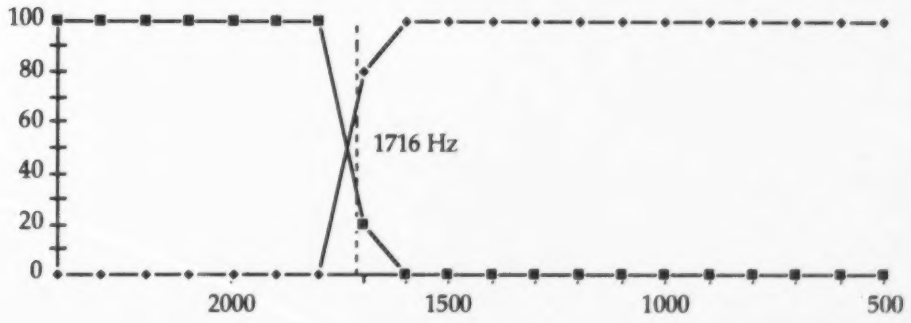
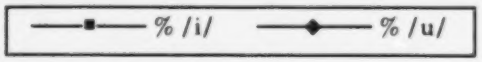
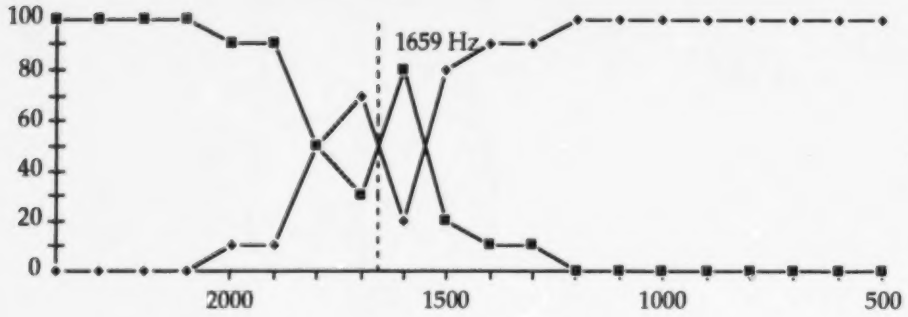


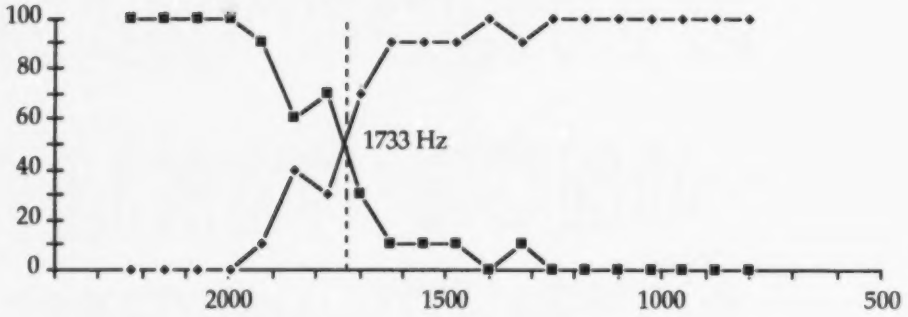
Figure 44: Identification percentage functions of the vowels /i/ and /u/ in synthetic signals by English listener En28. (See p. 234 for explanatory details.)



(a) English Listener En28: /V/



(b) English Listener En28: /bV/



(c) English Listener En28: /dV/

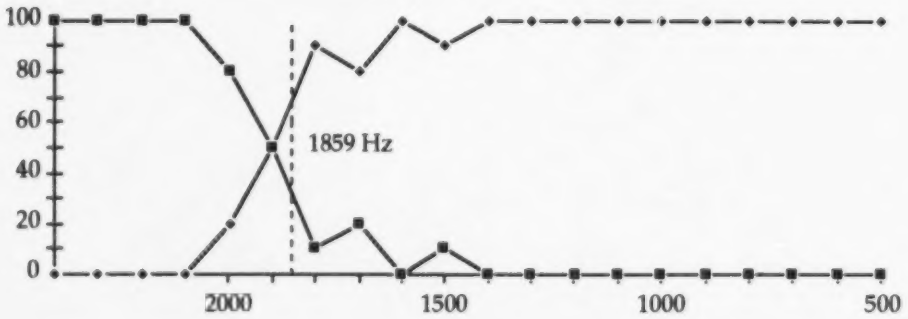


Figure 45: Identification percentage functions of the vowels /i/, /y/ and /u/ in synthetic signals by French listener Fr04. (See p. 234 for explanatory details.)

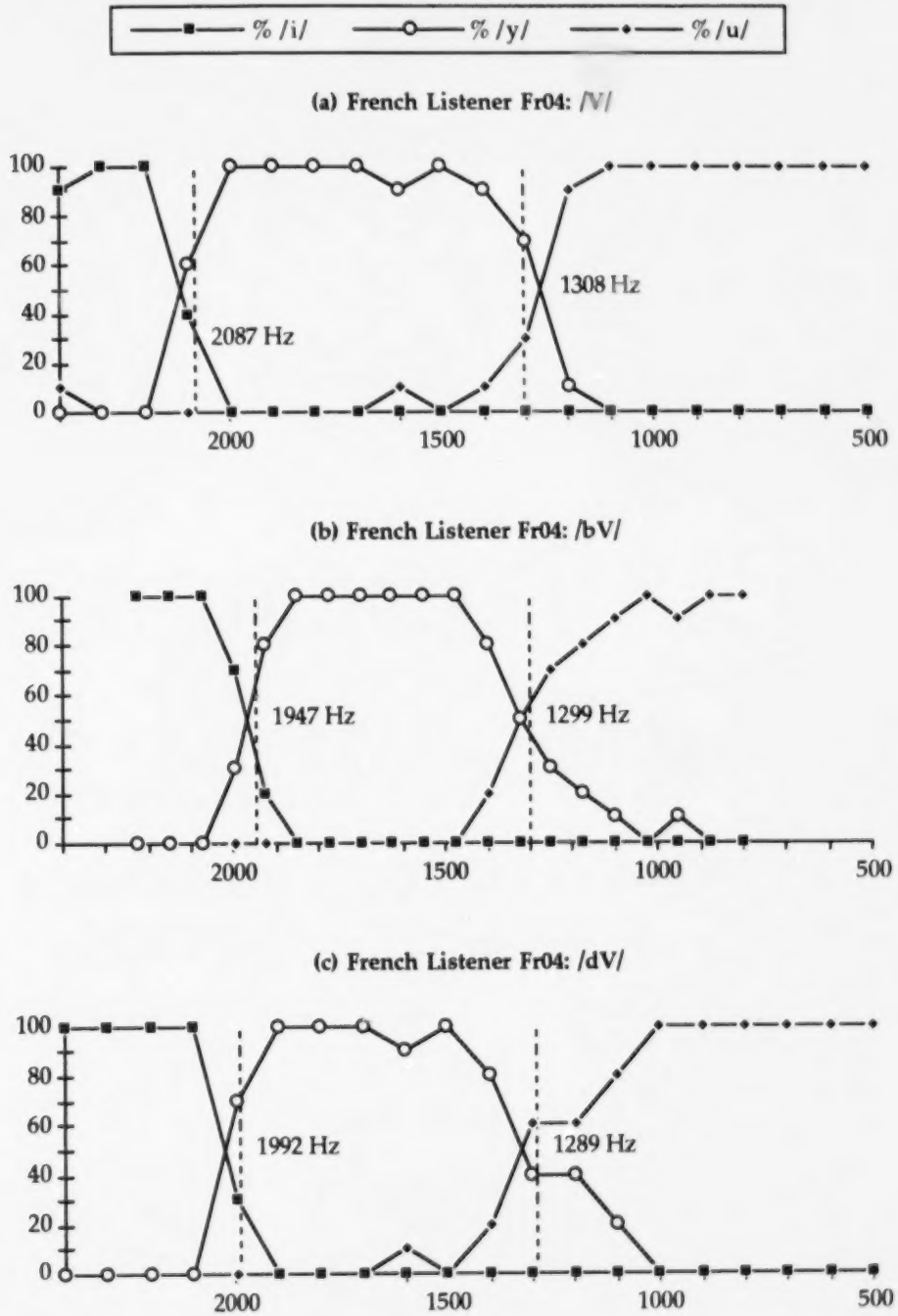
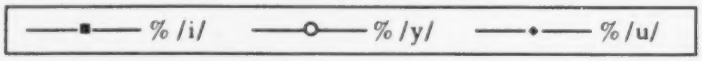
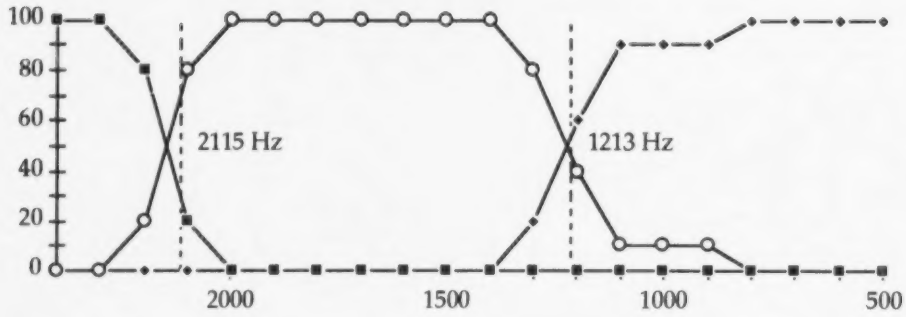


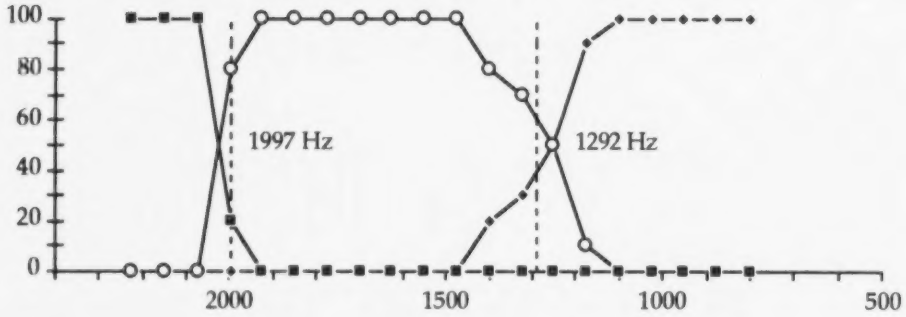
Figure 46: Identification percentage functions of the vowels /i/, /y/ and /u/ in synthetic signals by French listener Fr06. (See p. 234 for explanatory details.)



(a) French Listener Fr06: /V/



(b) French Listener Fr06: /bV/



(c) French Listener Fr06: /dV/

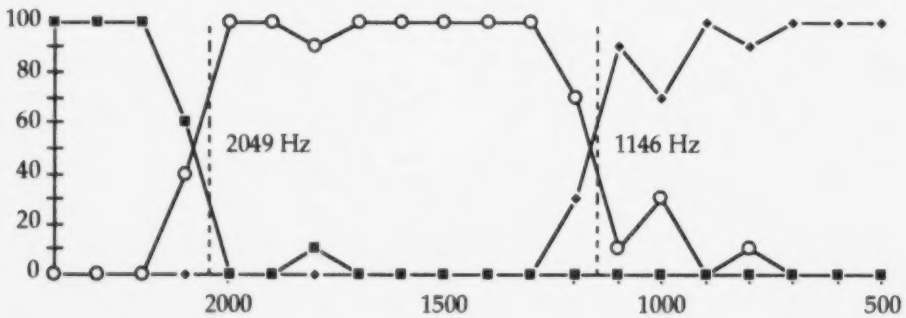
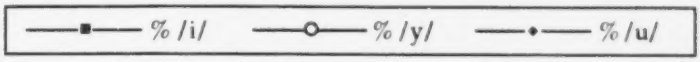
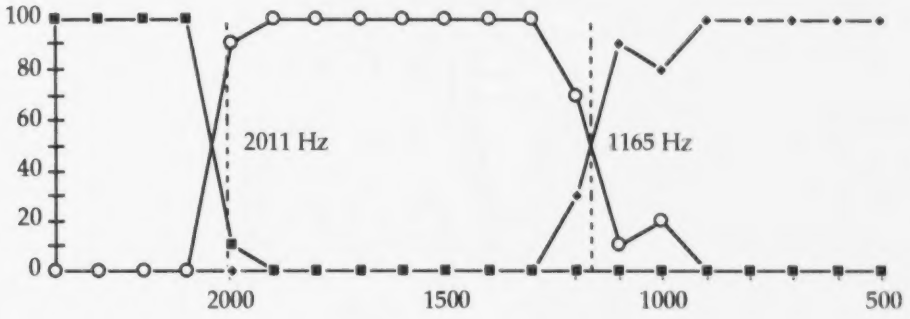


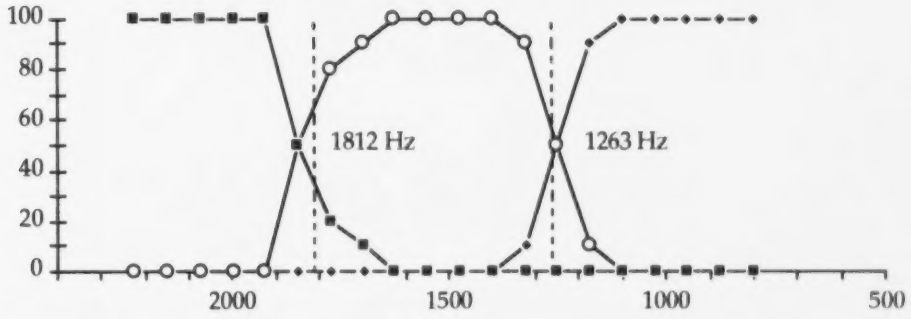
Figure 47: Identification percentage functions of the vowels /i/, /y/ and /u/ in synthetic signals by French listener Fr08. (See p. 234 for explanatory details.)



(a) French Listener Fr08: /V/



(b) French Listener Fr08: /bV/



(c) French Listener Fr08: /dV/

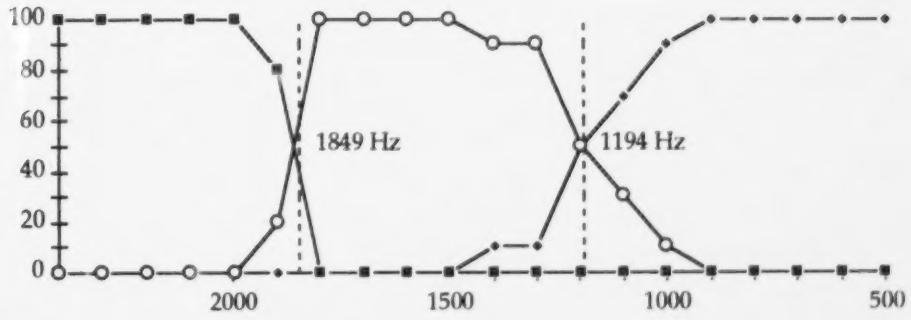
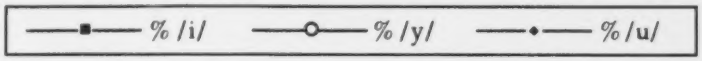
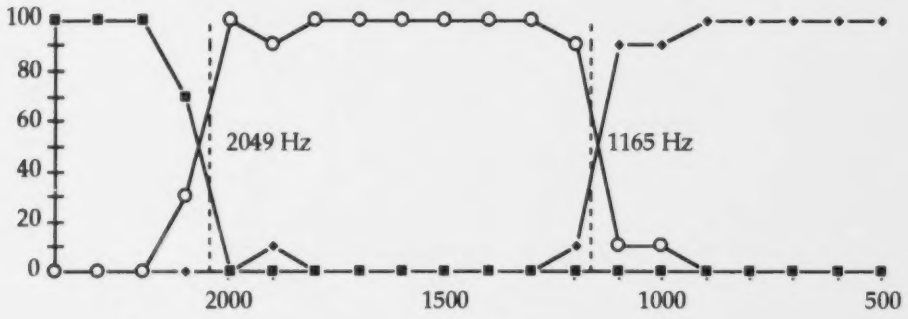


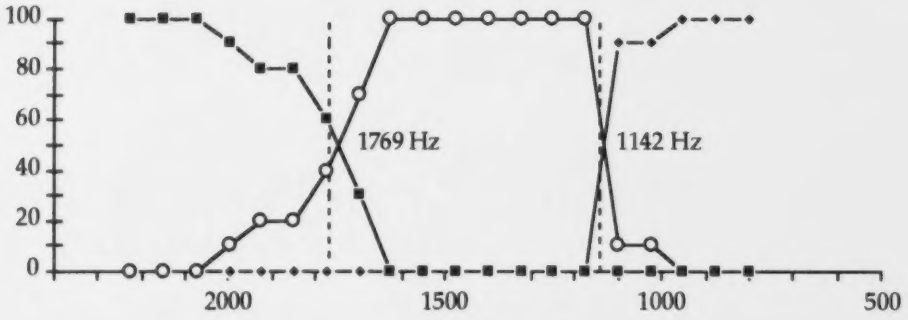
Figure 48: Identification percentage functions of the vowels /i/, /y/ and /u/ in synthetic signals by French listener Fr12. (See p. 234 for explanatory details.)



(a) French Listener Fr12: /V/



(b) French Listener Fr12: /bV/



(c) French Listener Fr12: /dV/

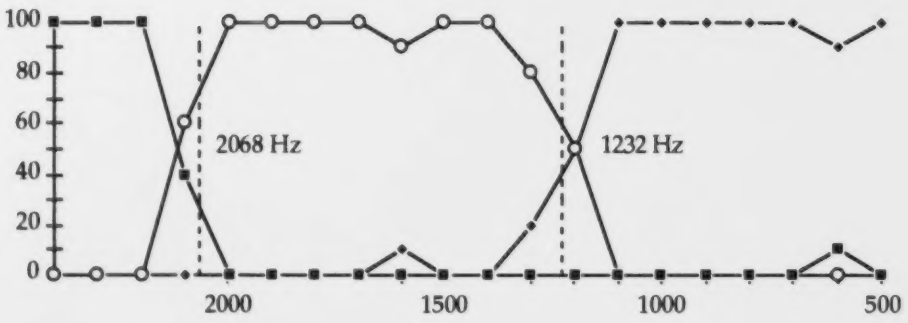


Figure 49: Identification percentage functions of the vowels /i/, /y/ and /u/ in synthetic signals by French listener Fr14. (See p. 234 for explanatory details.)

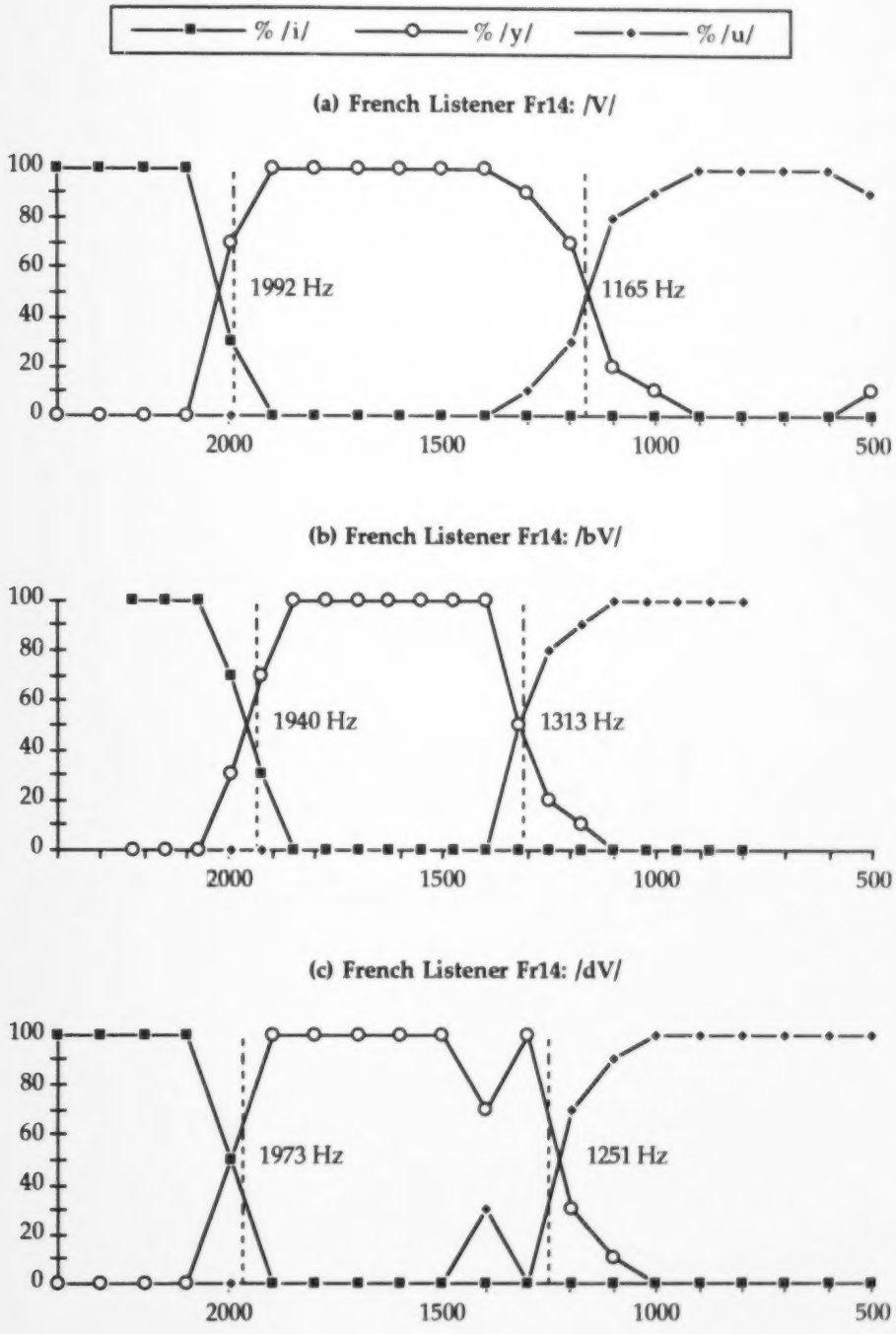
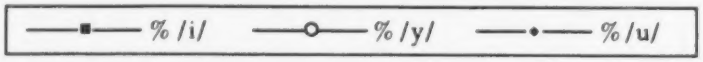
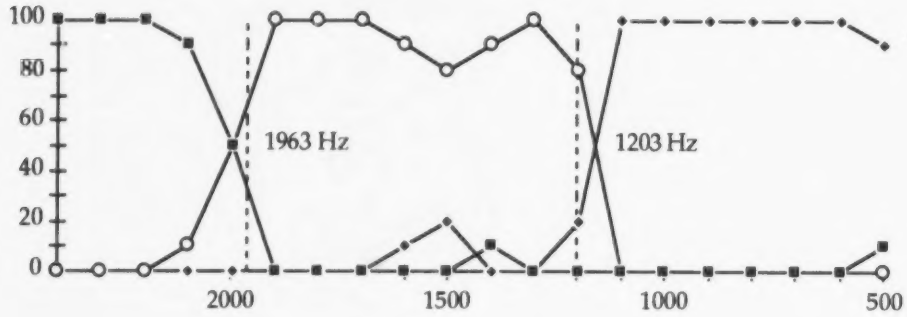


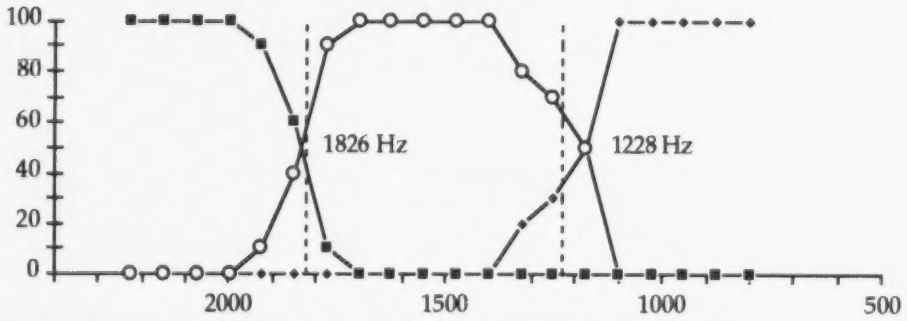
Figure 50: Identification percentage functions of the vowels /i/, /y/ and /u/ in synthetic signals by French listener Fr15. (See p. 234 for explanatory details.)



(a) French Listener Fr15: /V/

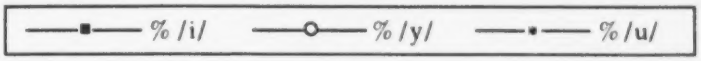


(b) French Listener Fr15: /bV/

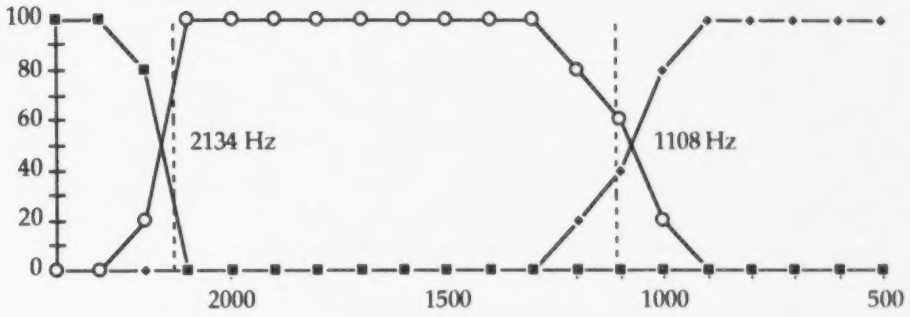


(c) French Listener Fr15: /dV/

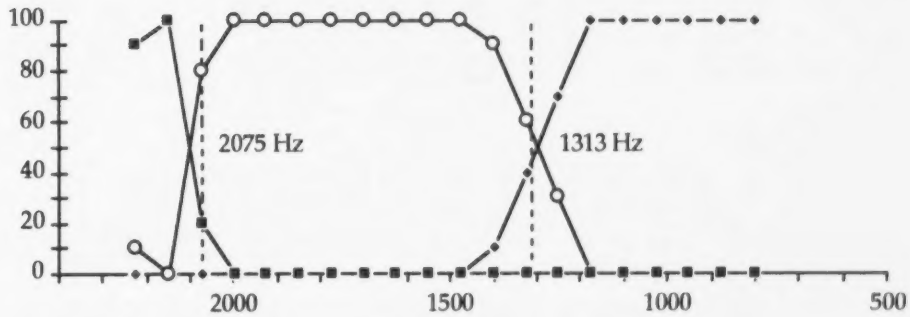
Figure 51: Identification percentage functions of the vowels /i/, /y/ and /u/ in synthetic signals by French listener Fr17. (See p. 234 for explanatory details.)



(a) French Listener Fr17: /V/



(b) French Listener Fr17: /bV/



(c) French Listener Fr17: /dV/

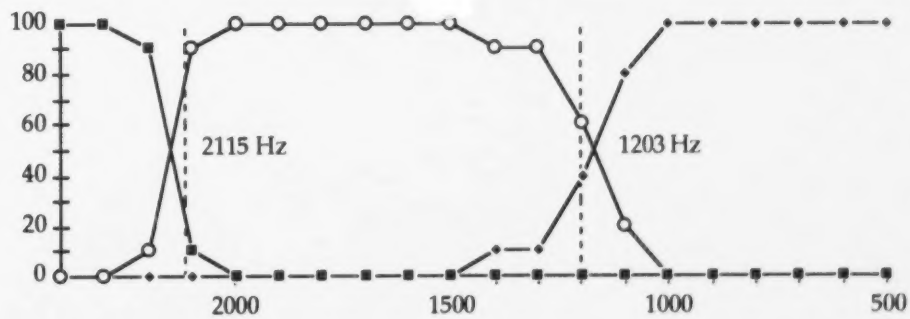
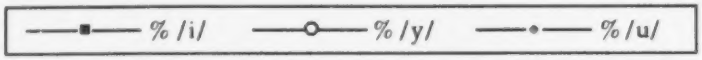
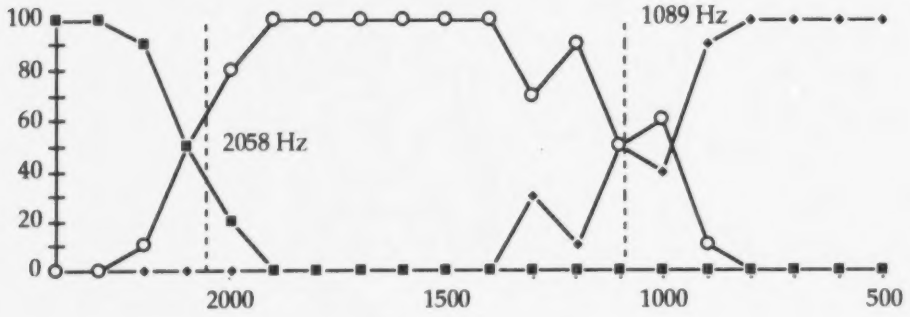


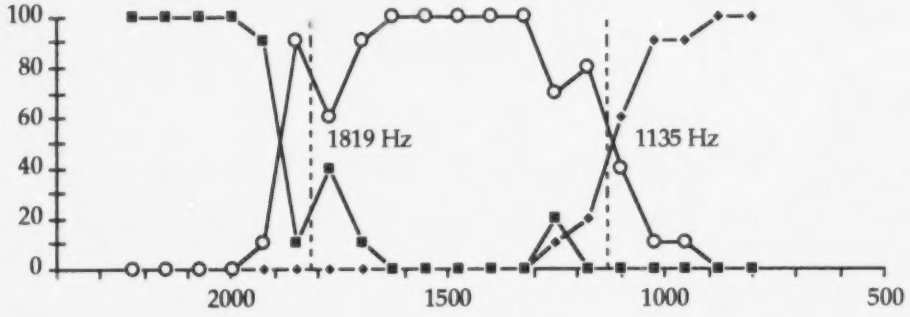
Figure 52: Identification percentage functions of the vowels /i/, /y/ and /u/ in synthetic signals by French listener Fr18. (See p. 234 for explanatory details.)



(a) French Listener Fr18: /V/



(b) French Listener Fr18: /bV/



(c) French Listener Fr18: /dV/

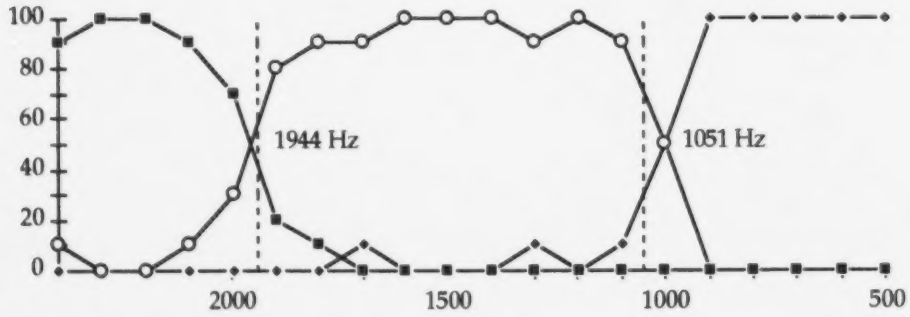
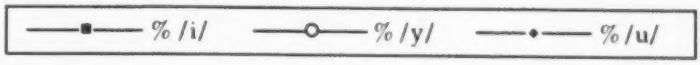
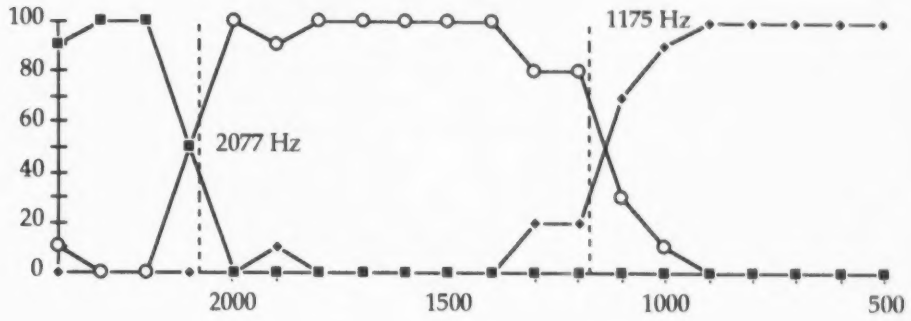


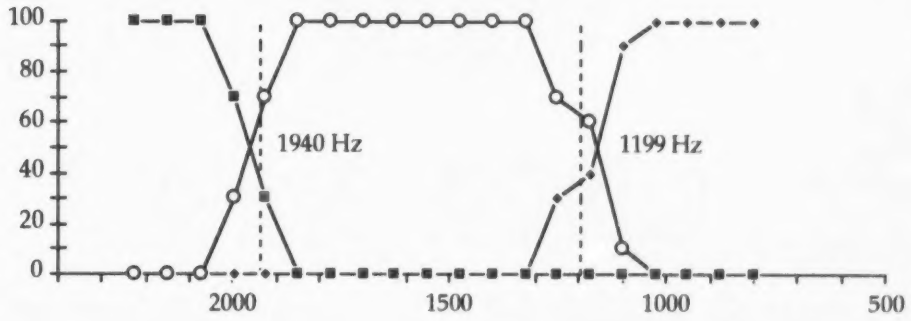
Figure 53: Identification percentage functions of the vowels /i/, /y/ and /u/ in synthetic signals by French listener Fr19. (See p. 234 for explanatory details.)



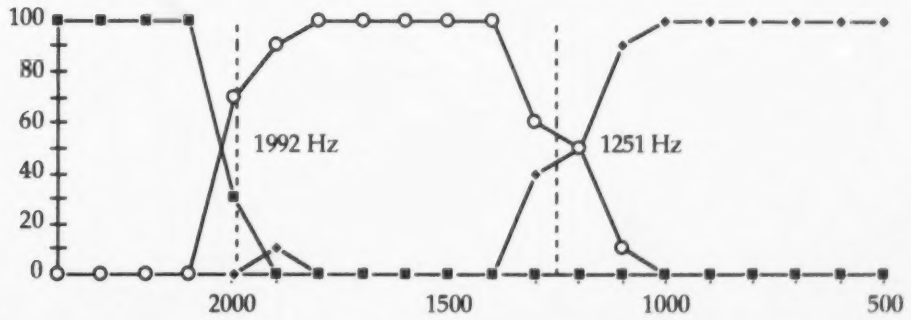
(a) French Listener Fr19: /V/



(b) French Listener Fr19: /bV/



(c) French Listener Fr19: /dV/



APPENDIX E

PERCEPTUAL TEST DATA—NATURAL SIGNALS

The tables in this section show the vowel identification resonses given by French Listeners to tokens of /u/ as produced by speakers of Canadian English. Tables are not shown for responses to English /i/, since, with a single exception, all were categorized as /i/ (see p. 167, above).

In these tables, the data of the first 4 listeners listed, Fr04, Fr10, Fr12 and Fr13, were not included in the analysis (see pp. 167-169, above). Three different proportion values are given on the right-hand side of the tables for each token in the test—the first for all listeners, the second for the excluded listeners alone, and the third for the retained listeners alone. In the computing of percentages, identifications as /i/ were treated as /y/s.

Table 28: Vowel identification resonses given by French Listeners to tokens of English /bub/ as produced by female speakers.

Female Spkrs		French Listeners: Fr...														Percentage		
Eng.	Token	Excluded Ss				Retained Ss										/y/ Responses		
Spkr	No.	04	10	12	13	01	03	05	07	08	14	15	17	18	19	All	Excl.	Ret.
En01	/bub/2	u	y	u	y	u	u	u	u	u	u	u	u	u	u	14	50	0
En01	/bub/3	u	u	u	u	y	u	u	u	y	u	u	u	u	u	14	0	20
En01	/bub/4	u	u	y	u	u	u	u	u	y	u	y	u	u	u	21	25	20
En01	/bub/5	u	y	u	u	y	u	u	u	y	u	u	y	y	u	36	25	40
En01	/bub/7	u	u	u	u	y	u	u	u	u	u	u	u	u	u	7	0	10
En01	/bub/8	u	u	u	u	u	u	u	u	u	u	u	u	u	u	0	0	0
En01	/bub/10	u	y	u	u	u	u	u	y	y	u	u	y	u	u	29	25	30
En03	/bub/1	u	y	u	u	y	u	u	u	y	u	u	y	u	y	36	25	40
En03	/bub/2	u	u	y	u	y	u	u	u	u	u	y	y	y	u	36	25	40
En03	/bub/4	u	y	u	u	u	u	u	u	u	u	u	u	u	u	7	25	0
En03	/bub/5	u	u	u	u	y	u	u	u	y	u	u	u	u	u	14	0	20
En03	/bub/7	u	u	u	u	y	u	u	u	y	u	u	u	u	u	14	0	20
En03	/bub/8	u	y	u	u	y	u	u	u	y	u	u	u	u	u	21	25	20
En03	/bub/9	u	u	u	u	u	u	u	u	u	u	u	u	u	u	0	0	0
En09	/bub/1	u	u	u	u	u	u	u	u	y	u	u	y	u	u	14	0	20
En09	/bub/2	u	y	y	u	y	u	u	y	u	u	y	y	u	u	43	50	40
En09	/bub/4	u	u	u	u	u	u	u	y	y	u	u	y	u	u	21	0	30
En09	/bub/6	u	y	u	u	y	u	u	u	y	u	y	y	u	u	36	25	40
En09	/bub/7	u	u	u	u	u	u	u	u	y	u	y	u	y	u	21	0	30
En09	/bub/8	u	y	y	u	y	u	u	y	y	u	y	y	y	u	57	50	60
En09	/bub/9	u	y	y	u	y	u	u	u	u	u	y	y	y	u	43	50	40
En13	/bub/1	u	u	u	u	u	u	u	u	u	u	u	u	u	u	0	0	0
En13	/bub/3	u	y	u	u	y	u	u	u	u	u	y	y	u	u	29	25	30
En13	/bub/4	u	y	y	y	u	u	u	u	u	u	u	u	y	u	29	75	10
En13	/bub/5	u	u	u	u	y	u	u	u	u	u	u	u	u	u	7	0	10
En13	/bub/6	u	u	u	u	u	u	u	u	u	u	u	u	u	u	0	0	0
En13	/bub/7	u	u	u	u	y	u	u	u	u	u	u	u	u	u	7	0	10
En13	/bub/10	u	u	y	u	y	u	u	u	y	u	u	y	u	u	29	25	30
En21	/bub/1	u	y	y	u	u	u	u	y	y	y	y	y	y	u	57	50	60
En21	/bub/2	u	y	y	u	y	u	u	u	y	u	y	u	u	u	36	50	30
En21	/bub/3	u	u	y	u	y	u	u	u	y	u	y	u	u	u	29	25	30
En21	/bub/4	u	u	y	u	y	u	u	y	u	u	y	y	u	u	36	25	40
En21	/bub/5	u	u	u	u	y	u	u	y	u	u	y	y	u	u	29	0	40
En21	/bub/7	u	u	u	u	u	u	u	u	y	u	u	u	u	u	7	0	10
En21	/bub/9	u	u	y	y	y	u	u	u	u	y	u	u	u	u	29	50	20
% /y/ Resp.		0	40	34	9	60	0	0	20	51	6	37	43	20	3	23	21	24

Table 29: Vowel identification resonses given by French Listeners to tokens of English /bub/ as produced by male speakers.

Male Spkrs		French Listeners: Fr...														Percentage		
Eng.	Token	Excluded Ss				Retained Ss										/y/ Responses		
Spkr	No.	04	10	12	13	01	03	05	07	08	14	15	17	18	19	All	Excl.	Ret.
En05	/bub/1	u	u	u	u	y	u	u	u	u	u	u	u	u	u	7	0	10
En05	/bub/2	u	u	u	u	u	u	u	u	u	u	u	u	u	u	0	0	0
En05	/bub/3	u	y	u	u	u	u	u	u	y	u	u	u	u	u	14	25	10
En05	/bub/4	u	u	u	u	u	u	u	u	u	u	u	u	u	u	0	0	0
En05	/bub/6	u	u	u	u	y	u	u	u	u	u	u	u	u	u	7	0	10
En05	/bub/8	u	u	u	u	y	u	u	u	u	u	u	y	u	u	14	0	20
En05	/bub/9	u	u	u	u	u	u	u	u	u	u	u	y	u	u	7	0	10
En14	/bub/2	u	y	y	i	y	u	u	u	u	u	y	u	u	u	36	75	20
En14	/bub/3	u	u	u	u	y	u	u	y	u	u	u	u	u	u	14	0	20
En14	/bub/4	u	u	u	u	u	u	u	u	u	u	u	y	u	u	7	0	10
En14	/bub/5	u	u	u	u	u	u	u	y	u	u	u	u	u	u	7	0	10
En14	/bub/6	u	u	u	u	y	u	u	y	u	u	u	u	u	u	14	0	20
En14	/bub/9	u	u	u	u	y	u	u	u	y	u	u	u	u	y	21	0	30
En14	/bub/10	u	u	u	u	y	u	u	u	u	u	u	u	u	u	7	0	10
En23	/bub/1	u	u	u	u	y	u	u	u	u	u	u	y	u	u	14	0	20
En23	/bub/3	u	u	u	u	y	u	u	u	y	u	u	u	u	u	14	0	20
En23	/bub/4	u	u	u	u	u	u	y	u	u	u	u	u	u	u	7	0	10
En23	/bub/7	u	u	u	u	y	u	y	u	u	u	u	u	u	u	14	0	20
En23	/bub/8	u	u	u	u	y	u	u	u	u	u	u	u	u	u	7	0	10
En23	/bub/9	u	y	u	u	y	u	u	u	u	u	u	u	u	u	14	25	10
En23	/bub/10	u	u	u	u	y	u	u	u	y	u	u	u	u	u	14	0	20
En24	/bub/2	u	u	u	u	u	u	u	u	u	u	u	u	u	u	0	0	0
En24	/bub/3	u	u	u	u	u	u	u	u	u	u	u	u	u	u	0	0	0
En24	/bub/4	u	u	u	u	u	u	u	u	u	u	u	u	u	u	0	0	0
En24	/bub/5	u	u	u	u	u	u	u	u	u	u	u	u	u	u	0	0	0
En24	/bub/6	u	u	u	u	y	u	u	u	u	u	u	u	u	u	7	0	10
En24	/bub/8	u	y	u	u	u	u	u	u	u	u	u	u	u	u	7	25	0
En24	/bub/9	u	u	u	u	u	u	u	u	u	u	u	y	u	u	7	0	10
En28	/bub/1	u	y	u	u	u	u	u	y	u	u	y	u	u	y	29	25	30
En28	/bub/4	u	y	u	u	y	u	u	u	u	u	u	y	u	u	21	25	20
En28	/bub/5	u	y	y	y	y	u	u	y	y	y	y	y	y	y	79	75	80
En28	/bub/7	u	u	u	u	y	u	u	u	u	u	u	u	u	u	7	0	10
En28	/bub/8	u	u	y	u	u	u	u	u	y	u	y	u	u	u	21	25	20
En28	/bub/9	u	u	u	u	u	u	u	u	u	u	u	u	u	u	0	0	0
En28	/bub/10	u	u	u	u	u	u	u	y	y	u	u	u	u	u	14	0	20
% /y/ Resp.		0	20	9	6	51	0	6	17	20	3	11	20	3	9	12	9	14

Table 30: Vowel identification resonses given by French Listeners to tokens of English /gug/ as produced by female speakers.

Female Spkrs		French Listeners: Fr...														Percentage		
Eng.	Token	Excluded Ss				Retained Ss										/y/ Responses		
Spkr	No.	04	10	12	13	01	03	05	07	08	14	15	17	18	19	All	Excl.	Ret.
En01	/gug/1	u	y	u	u	u	y	u	u	u	u	y	y	u	y	36	25	40
En01	/gug/2	u	y	u	u	u	u	y	u	y	u	y	u	y	u	36	25	40
En01	/gug/3	u	y	u	u	u	y	u	u	u	u	y	u	y	u	29	25	30
En01	/gug/4	u	y	y	u	u	u	u	u	u	u	y	y	y	u	36	50	30
En01	/gug/5	u	y	u	u	u	u	u	y	u	u	y	y	u	y	36	25	40
En01	/gug/6	u	u	u	u	u	u	u	u	y	u	y	u	u	u	14	0	20
En01	/gug/7	u	y	y	u	u	u	y	u	u	u	y	u	u	y	36	50	30
En03	/gug/2	u	y	u	u	u	u	u	u	u	u	u	u	u	u	7	25	0
En03	/gug/3	u	y	u	y	u	u	u	u	u	u	u	u	u	u	14	50	0
En03	/gug/4	u	y	y	u	u	u	u	u	u	u	u	u	u	u	14	50	0
En03	/gug/5	u	y	u	u	u	u	u	u	u	u	u	u	u	y	14	25	10
En03	/gug/6	u	u	u	u	u	u	u	u	u	u	u	y	u	u	7	0	10
En03	/gug/7	u	u	u	u	u	u	y	u	u	u	y	u	y	u	21	0	30
En03	/gug/8	u	y	u	ʊ	u	u	u	u	y	u	u	u	u	u	14	25	10
En09	/gug/2	u	y	u	u	u	u	y	u	u	u	y	u	u	u	21	25	20
En09	/gug/4	u	y	u	u	u	u	u	u	y	u	y	u	u	u	21	25	20
En09	/gug/5	u	y	y	u	u	u	u	y	y	u	y	u	y	u	43	50	40
En09	/gug/7	u	y	y	u	u	u	u	u	u	u	y	u	u	u	21	50	10
En09	/gug/8	u	y	y	u	u	u	u	u	y	u	y	y	u	u	36	50	30
En09	/gug/9	u	y	u	u	u	u	u	u	y	y	y	u	u	u	29	25	30
En09	/gug/10	u	y	y	y	u	u	u	u	y	u	y	y	y	u	50	75	40
En13	/gug/2	u	y	u	y	u	u	u	y	u	u	y	u	u	y	36	50	30
En13	/gug/3	u	y	u	u	u	u	u	u	u	u	u	u	u	u	7	25	0
En13	/gug/6	u	u	u	u	u	u	u	u	y	u	y	u	y	u	21	0	30
En13	/gug/7	u	y	u	u	y	u	u	u	u	u	u	u	u	u	14	25	10
En13	/gug/8	u	y	y	u	u	u	u	u	y	u	y	u	y	y	43	50	40
En13	/gug/9	u	y	u	u	u	u	u	u	u	u	u	u	u	u	7	25	0
En13	/gug/10	u	y	u	u	u	u	u	u	u	u	u	u	y	u	14	25	10
En21	/gug/1	u	y	u	u	u	u	u	u	y	u	y	y	u	y	36	25	40
En21	/gug/3	u	y	u	u	u	u	u	u	y	u	u	u	u	u	14	25	10
En21	/gug/5	u	u	y	u	u	u	u	u	y	u	y	u	u	y	29	25	30
En21	/gug/7	u	y	y	u	u	u	y	u	y	u	y	y	y	u	50	50	50
En21	/gug/8	u	y	y	u	u	u	u	u	u	u	y	u	y	y	36	50	30
En21	/gug/9	u	y	u	u	u	u	u	u	u	u	y	u	u	y	21	25	20
En21	/gug/10	u	y	y	u	y	u	u	u	u	u	y	y	y	u	43	50	40
% /y/ Resp.		0	86	34	9	6	6	14	9	40	3	69	26	34	29	26	32	23

Table 31: Vowel identification resonses given by French Listeners to tokens of English /gug/ as produced by male speakers.

Male Spkrs		French Listeners: Fr...														Percentage		
Eng.	Token	Excluded Ss				Retained Ss										/y/ Responses		
Spkr	No.	04	10	12	13	01	03	05	07	08	14	15	17	18	19	All	Excl.	Ret.
En05	/gug/2	u	y	u	u	u	u	u	u	u	u	u	u	u	u	7	25	0
En05	/gug/3	u	y	u	u	u	u	u	u	u	u	u	u	u	u	7	25	0
En05	/gug/6	u	y	u	y	u	u	u	y	u	u	u	y	u	y	36	50	30
En05	/gug/7	u	y	u	u	u	u	y	u	u	u	u	y	u	u	21	25	20
En05	/gug/8	u	y	y	u	u	u	u	u	y	u	u	u	u	u	21	50	10
En05	/gug/9	u	y	u	u	u	u	u	u	u	u	u	u	u	u	7	25	0
En05	/gug/10	u	y	u	u	u	u	u	u	u	u	u	y	u	u	14	25	10
En14	/gug/1	u	y	u	u	u	u	u	u	u	u	y	u	u	u	14	25	10
En14	/gug/3	u	y	u	u	u	u	y	u	u	u	u	y	u	u	21	25	20
En14	/gug/4	u	u	u	u	u	u	u	u	y	u	y	u	u	u	14	0	20
En14	/gug/5	u	u	u	u	u	u	u	u	y	u	u	y	u	y	21	0	30
En14	/gug/6	u	y	u	y	u	u	u	u	u	u	u	y	u	u	21	50	10
En14	/gug/8	u	y	u	u	u	u	u	u	u	u	u	y	u	u	14	25	10
En14	/gug/9	u	y	u	u	u	u	u	u	u	u	u	u	u	u	7	25	0
En23	/gug/1	u	u	u	u	u	u	u	u	u	u	u	u	u	u	0	0	0
En23	/gug/2	u	y	u	u	u	u	u	u	y	u	u	y	u	u	21	25	20
En23	/gug/4	u	u	u	u	u	u	u	u	u	u	u	u	u	u	0	0	0
En23	/gug/5	u	u	u	u	u	u	u	u	u	u	u	u	u	u	0	0	0
En23	/gug/6	u	y	u	y	u	u	u	u	u	u	u	u	u	u	14	50	0
En23	/gug/8	u	y	u	u	u	u	u	u	u	u	u	u	u	u	7	25	0
En23	/gug/9	u	y	u	u	u	u	u	u	u	u	u	u	u	u	7	25	0
En24	/gug/1	u	y	u	u	u	u	y	u	u	u	u	y	u	u	21	25	20
En24	/gug/2	u	y	u	u	u	u	u	u	u	u	u	u	u	u	7	25	0
En24	/gug/5	u	y	u	u	u	u	u	u	u	u	u	u	y	u	14	25	10
En24	/gug/6	u	y	u	u	u	u	u	u	u	u	u	u	u	u	7	25	0
En24	/gug/7	u	u	u	u	u	u	u	u	u	u	u	y	u	u	7	0	10
En24	/gug/8	u	u	u	u	u	u	u	u	u	u	u	u	u	u	0	0	0
En24	/gug/10	u	y	u	u	u	u	u	u	u	u	u	u	u	u	7	25	0
En28	/gug/1	u	u	u	u	u	u	u	u	u	u	y	u	u	u	7	0	10
En28	/gug/2	u	y	u	u	u	u	u	u	u	u	y	y	u	y	29	25	30
En28	/gug/4	u	y	u	u	u	u	u	y	u	u	u	y	u	u	21	25	20
En28	/gug/5	u	y	u	u	y	u	u	u	u	u	u	y	u	u	21	25	20
En28	/gug/7	u	y	y	u	u	u	u	u	y	u	u	y	u	y	36	50	30
En28	/gug/8	u	u	u	u	u	y	u	u	y	u	u	u	y	y	29	0	40
En28	/gug/9	u	y	u	u	y	u	u	u	u	u	y	u	u	u	21	25	20
% /y/ Resp.		0	74	6	9	6	3	9	6	17	0	14	40	6	14	14	22	11

Table 32: Vowel identification resonses given by French Listeners to tokens of English /dud/ as produced by female speakers.

Female Spkrs		French Listeners: Fr...														Percentage		
Eng.	Token	Excluded Ss				Retained Ss										/y/ Responses		
Spkr	No.	04	10	12	13	01	03	05	07	08	14	15	17	18	19	All	Excl.	Ret.
En01	/dud/1	u	y	u	i	y	y	y	u	y	u	y	y	y	y	71	50	80
En01	/dud/4	u	u	u	u	y	y	u	u	u	y	y	y	y	y	50	0	70
En01	/dud/5	u	u	u	u	y	y	y	y	u	y	y	y	y	u	57	0	80
En01	/dud/6	u	u	u	u	y	y	y	u	y	y	y	y	y	u	57	0	80
En01	/dud/8	u	y	u	y	y	y	y	y	y	u	y	y	y	y	79	50	90
En01	/dud/9	u	u	u	u	y	u	y	y	y	u	y	y	y	u	50	0	70
En01	/dud/10	u	u	u	i	y	u	y	u	u	u	y	y	y	y	50	25	60
En03	/dud/2	u	y	u	u	y	u	y	u	y	u	y	y	u	u	43	25	50
En03	/dud/4	u	u	u	y	y	u	u	u	u	u	y	y	y	u	36	25	40
En03	/dud/5	u	y	u	y	y	u	y	u	y	y	y	y	u	y	64	50	70
En03	/dud/6	u	u	u	u	y	u	y	y	y	y	y	u	u	u	43	0	60
En03	/dud/7	u	y	u	y	u	u	y	y	y	y	y	y	u	y	64	50	70
En03	/dud/8	i	u	u	i	y	u	y	y	y	y	i	y	u	y	71	50	80
En03	/dud/9	u	u	u	y	y	u	u	u	y	y	y	u	y	u	43	25	50
En09	/dud/1	u	u	u	i	y	u	y	y	y	y	y	y	y	y	71	25	90
En09	/dud/4	u	y	u	i	y	y	y	y	y	y	y	y	u	y	79	50	90
En09	/dud/5	u	i	u	y	y	y	y	y	y	y	y	y	y	y	86	50	100
En09	/dud/6	u	u	u	i	y	y	y	y	y	y	y	y	y	u	71	25	90
En09	/dud/7	u	u	u	i	i	y	y	y	y	y	y	y	y	y	79	25	100
En09	/dud/9	u	u	u	u	y	y	u	y	y	y	y	y	y	y	64	0	90
En09	/dud/10	u	u	u	i	y	u	u	y	y	y	y	y	y	y	64	25	80
En13	/dud/1	u	u	u	i	y	u	y	u	y	u	u	y	u	u	36	25	40
En13	/dud/2	u	u	u	u	y	u	u	u	y	y	y	u	u	u	29	0	40
En13	/dud/3	u	u	u	u	u	y	u	y	y	u	u	y	y	u	36	0	50
En13	/dud/5	u	u	u	u	y	u	y	u	y	y	y	y	u	u	43	0	60
En13	/dud/6	u	u	u	u	y	u	y	y	y	y	y	u	u	u	43	0	60
En13	/dud/7	u	u	u	u	y	u	u	y	y	y	y	u	u	u	36	0	50
En13	/dud/10	u	u	u	u	u	u	u	y	y	u	u	u	u	u	14	0	20
En21	/dud/1	u	u	u	i	y	u	u	y	y	y	y	y	u	y	57	25	70
En21	/dud/2	u	y	u	i	y	u	u	u	y	u	y	y	y	y	57	50	60
En21	/dud/5	u	u	u	y	y	u	y	y	y	y	y	u	y	u	57	25	70
En21	/dud/6	u	y	y	i	y	u	u	y	y	y	y	y	u	y	71	75	70
En21	/dud/7	u	y	y	i	y	y	y	y	y	y	y	y	y	u	86	75	90
En21	/dud/9	u	y	u	u	y	y	y	y	y	y	y	y	u	y	71	25	90
En21	/dud/10	u	u	u	i	y	u	y	y	y	y	y	y	y	y	71	25	90
% /y/ Resp.		3	31	6	60	91	37	66	66	89	71	91	80	57	51	57	25	70

Table 33: Vowel identification resonses given by French Listeners to tokens of English /dud/ as produced by male speakers.

Male Spkrs		French Listeners: Fr...														Percentage		
Eng.	Token	Excluded Ss				Retained Ss										/y/ Responses		
Spkr	No.	04	10	12	13	01	03	05	07	08	14	15	17	18	19	All	Excl.	Ret.
En05	/dud/1	u	u	u	u	y	y	u	y	y	u	u	y	u	u	36	0	50
En05	/dud/3	u	u	u	u	y	u	y	u	u	y	y	y	y	u	43	0	60
En05	/dud/5	u	u	u	u	y	u	u	u	y	u	u	u	y	u	21	0	30
En05	/dud/6	u	u	u	u	y	u	y	y	u	u	y	y	y	u	43	0	60
En05	/dud/7	u	u	u	u	y	u	y	y	u	u	u	y	u	u	29	0	40
En05	/dud/8	u	u	u	u	y	u	u	u	y	u	u	y	u	u	21	0	30
En05	/dud/9	u	u	u	u	y	u	u	u	u	u	y	u	u	u	14	0	20
En14	/dud/2	u	u	u	u	y	u	y	u	y	u	y	u	u	u	29	0	40
En14	/dud/3	u	u	u	y	y	u	u	u	u	y	u	y	u	y	36	25	40
En14	/dud/4	u	u	u	u	y	u	u	u	y	y	u	u	u	u	21	0	30
En14	/dud/5	u	u	u	u	y	y	y	u	y	u	y	y	y	u	50	0	70
En14	/dud/6	u	u	u	u	y	u	u	u	y	u	u	y	u	y	29	0	40
En14	/dud/7	u	u	u	u	y	u	y	u	y	u	y	y	y	y	50	0	70
En14	/dud/9	u	u	u	u	y	u	u	u	y	u	u	y	u	u	21	0	30
En23	/dud/1	u	u	u	u	y	u	u	u	y	u	u	y	u	u	21	0	30
En23	/dud/2	u	u	u	u	y	u	u	u	y	u	u	u	u	u	14	0	20
En23	/dud/3	u	u	u	u	y	u	u	u	y	u	y	u	u	u	21	0	30
En23	/dud/4	u	u	y	u	y	u	y	u	y	y	y	y	y	u	57	25	70
En23	/dud/5	u	u	u	u	y	u	y	u	y	u	y	u	y	y	43	0	60
En23	/dud/6	u	u	u	u	y	u	u	y	u	u	y	y	y	u	36	0	50
En23	/dud/8	u	u	y	u	y	y	y	u	y	u	y	y	y	u	57	25	70
En24	/dud/1	u	u	u	u	y	y	y	y	y	u	y	u	y	y	57	0	80
En24	/dud/2	u	u	u	u	u	u	y	u	y	y	y	y	u	y	43	0	60
En24	/dud/3	u	u	u	u	y	y	u	y	y	u	y	u	y	y	50	0	70
En24	/dud/6	u	u	u	u	y	u	y	u	y	u	u	y	u	u	29	0	40
En24	/dud/7	u	u	u	u	y	y	y	u	y	u	u	u	y	u	36	0	50
En24	/dud/8	u	u	u	u	y	u	y	u	u	u	u	y	u	y	29	0	40
En24	/dud/10	u	u	u	u	y	u	y	y	u	y	u	u	y	u	36	0	50
En28	/dud/1	u	u	y	u	y	u	y	u	y	u	y	y	y	y	57	25	70
En28	/dud/2	u	u	u	u	u	u	y	y	y	u	y	y	u	u	36	0	50
En28	/dud/3	u	y	u	u	y	u	y	u	y	y	y	y	u	y	57	25	70
En28	/dud/5	u	u	u	u	y	u	u	y	y	u	i	u	y	u	36	0	50
En28	/dud/7	u	u	u	u	y	u	u	y	y	y	y	y	y	u	50	0	70
En28	/dud/9	u	u	y	y	y	y	y	y	y	y	y	y	y	u	79	50	90
En28	/dud/10	u	u	u	u	u	u	y	y	u	u	y	y	y	y	43	0	60
% /y/ Resp.		0	3	11	6	91	20	57	34	74	26	60	66	51	31	38	5	51